AMERICAN PSYCHOLOGICAL ASSOCIATION

Developmental Psychology

ISSN: 0012-1649

2024, Vol. 60, No. 10, 1785–1800
https://doi.org/10.1037/dev0001785

Individual Differences in Categorization Development: The Mediation of Executive Functions and Factual Knowledge, the Case of Food

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Cognitive mechanisms underpinning categorization development are still debated, either resulting from knowledge accretion or an increase in cognitive control. To disentangle the respective influence of accumulated factual knowledge and executive functions (inhibition, working memory, and cognitive flexibility) on (a) the development of categorization abilities in the food domain and (b) differences in this development by child characteristics (i.e., food neophobia), we conducted two experiments. The first experiment assessed 4–6-year-old children's (n = 122) ability to taxonomically categorize food at the superordinate level of categorization. The second experiment tested 3–6-year-old children's (n = 100) ability to cross-categorize the same food according to two different relationships alternatively (i.e., taxonomic and thematic). Results indicate that accumulated factual knowledge and executive functions mediated both the effect of age and the effect of food neophobia on categorization performance. Notably, the specific executive functions involved may vary depending on the categorization abilities tested, whereas world knowledge was always a prerequisite. Overall, this research highlights the complex interplay between accumulated factual knowledge, executive functions, and child characteristics in shaping the development of categorization abilities.

Public Significance Statement

During development, children learn to categorize objects by identifying relevant features that distinguish them from others. Categorization becomes increasingly flexible, allowing children to categorize the same entity into different categories depending on the context. This study investigates the mechanisms underlying this development and reveals that while knowledge is essential for accurate categorization, it is not enough. Children also need sufficiently developed executive functions to effectively apply their knowledge.

Keywords: categorization, world knowledge, executive functions, food neophobia, individual differences

Categorization is one of the most fundamental cognitive functions. During development, children must identify the relevant features for object categorization and discrimination. However, objects rarely fall into a single category. For example, when a child is presented with an apple, it could be seen as an "apple," a "Golden apple," a "fruit," a "food," a "dessert," or even "a food to eat on a diet." This means that, depending on the context, the *same* entity can be categorized into various categories, with each categorization highlighting different

This article was published Online First August 29, 2024.

Koraly Pérez-Edgar served as action editor.

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This work was supported by the Conseil Régional de Bourgogne, the Institut Lyfe Research and Innovation Center via the VarIété AlimenTaIre et développement Cognitif chez l'enfAnt de 4 à 6 ans project, and the Bases coGnitives d'une Education aLimentaire fondée sur la preuve à destination des enfants de 3 à 6 ans project cofunded by Grant ANR-21-PRRD-0047-01 and the Institut Lyfe Research Center (Jean-Pierre Thibaut and Jérémie Lafraire). This research was funded in whole, or in part, by the French National Research Agency (ANR-21-PRRD-0047-01). For the purpose of open access, the author has applied a CC BY public copyright license to any Author Accepted Manuscript version arising from this submission. The authors thank the children, their parents, and schools for their contributions and Yannick Lagarrigue, Eleanor Stansbury, Romane Borel, Marianne Dumaray, and Valentin Goncalves for their help in collecting the data. The authors have no conflicts of interest to declare.

Neither the study nor the analysis plan was preregistered. However, the materials for the categorization tasks were made available earlier (Foinant, 2021), and the analysis code for all studies are publicly available on the Open Science Framework at https://osf.io/fdx2z/. Additional online materials are available at https://osf.io/fdx2z/.

Damien Foinant contributed to conceptualization, methodology, investigation, data curation, formal analysis, visualization, writing–original draft, and writing–review and editing. Jérémie Lafraire contributed to conceptualization, funding acquisition, project administration, resources, supervision, and writing–review and editing. Jean-Pierre Thibaut contributed to conceptualization, funding acquisition, project administration, resources, supervision, writing–original draft, and writing–review and editing.

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properties (Nguyen & Gelman, 2012). This ability to categorize the *same* object in multiple categories, depending on the context, has been called cross-categorization (Blaye & Bonthoux, 2001; Blaye et al., 2006; Nguyen & McDermott, 2024). It is a fundamental feature of human cognition that allows us to adjust to a vast number of different situations. Indeed, according to Murphy and Medin (1985), any object can belong to a large number of categories, some stable (e.g., an apple), and others are ad hoc categories, built on the spot, such as "food to eat on a diet" (Barsalou, 1983).

Food serves as a prime example of a conceptual domain requiring flexibility in categorization. In their seminal study on cross-categorization and organization, Ross and Murphy (1999) selected this conceptual domain because "it is a rich real-world category domain (… as) we eat food, smell it, plan meals, read about it, talk about it, see it advertised, etc." (p. 495). The authors found that adults spontaneously group food into taxonomic categories (e.g., fruits, meats, dairy) and thematic categories (e.g., birthday foods, snacks). Their experiments demonstrated that cross-categorization is ubiquitous in the rich, complex conceptual domain of food.

Building upon the work of Ross and Murphy (1999), Nguyen and Murphy (2003) explored the development of cross-categorization in preschool children within the food domain. Their experiments revealed that children as young as 3 years of age could cross-categorize food based on either taxonomic or thematic criteria (see also Nguyen, 2007). Although a substantial body of literature has documented various aspects of children's categorization and cross-categorization (Blaye & Jacques, 2009; Carey, 1985; Gelman & Markman, 1986; Murphy, 2002; Nguyen, 2007, 2012; Nguyen & Murphy, 2003; Thibaut et al., 2016), to our knowledge, to date, no study *explicitly* investigated the underlying cognitive mechanisms involved in the development of these abilities. In the present research, we aim to investigate the respective influence of accumulated factual knowledge and executive functions on age-related improvements in categorization abilities in the food domain.

However, categorization development is often examined in relation to age, while individual differences among children are frequently disregarded, except in cases of cognitive impairment or intellectual deficiencies (Comblain et al., 2023). Recent research in the food domain has revealed that food neophobia, which pertains to how children approach novel food, negatively affects the development of category-based abilities (Foinant et al., 2022a; Pickard et al., 2021, 2023; Rioux et al., 2016, 2018a). The present study aims to explore the underlying mechanisms and investigate the mediating effects of accumulated factual knowledge and executive functions on the observed relationship between food neophobia and categorization. To achieve our objectives, we will employ two categorization tasks: a taxonomic categorization task and a cross-categorization task involving switching between taxonomic and thematic food categories.

The development of categorization and cross-categorization abilities is usually explained by accretion of world knowledge (Gelman, 2003; Gentner & Hoyos, 2017; Murphy, 2002; Oakes & Madole, 2003). The intuitive and appealing idea is that, as children grow, they gain more knowledge about the world, which enables them to build increasingly sophisticated conceptual systems. A deeper understanding of a specific conceptual domain is correlated with the ability to envision different ways of categorizing and, later, explaining the same object (Murphy & Medin, 1985). This knowledge-based view posits that children must possess sufficient knowledge of the corresponding thematic and taxonomic categories to effectively categorize and cross-categorize objects.

A less explored avenue of research related to the development of categorization is cognitive control and executive functions (Bascandziev et al., 2018; Grenell & Carlson, 2021; Lagarrigue & Thibaut, 2020; Simms et al., 2018; Tardiff et al., 2020; Vosniadou et al., 2018; Zaitchik et al., 2014). According to this approach, the development of children's categorization abilities is correlated with the development of their executive functions, which allows them to handle the cognitive load elicited by increasingly complex categorization situations, such as cross-categorization.

Executive functions is an umbrella term for cognitive processes that control other cognitive processes or systems and a key constituent of what is referred to as cognitive monitoring (Stemmer & Rodden, 2015). Executive functions encompass the coordination of attention and actions for intentional, goal-directed behavior (for a review, see Diamond, 2013). They develop from early childhood to late adolescence. As children grow, three separable yet correlated functions emerge: working memory, inhibitory control, and cognitive flexibility (Miyake et al., 2000; Wiebe et al., 2011).

Working memory is the ability to hold information in mind and mentally manipulate it (Diamond, 2006). Working memory's capacity increases as children mature, allowing them to hold and manipulate more information and tackle tasks with greater representational demands (Gathercole et al., 2004).

Inhibition is the ability to suppress attention and/or action toward prepotent, irrelevant, or conflicting information. It develops from late infancy onward as children's focus on relevant information slowly improves (Davidson et al., 2006).

Cognitive flexibility is defined as the ability to switch between perspectives (Diamond, 2013). It involves thinking about something in multiple ways, efficiently switching goals or activities, and adapting to changing task demands (Blaye, 2022). Cognitive flexibility improves as children develop, enabling them to successfully negotiate more complex tasks with shifting attentional demands or rule sets (Zelazo et al., 1996).

A few studies have explored the relationships between independent measures of executive functions and conceptual tasks. For instance, Zaitchik et al. (2014) adopted a correlational approach, examining the links between executive functions and conceptual knowledge in the biological domain. They examined the development of vitalist reasoning in children aged 5–7 while controlling for knowledge base width with the Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 2007), a receptive vocabulary test. Vocabulary tests are often used as a measure of accumulated factual knowledge (e.g., Bascandziev et al., 2018; Tardiff et al., 2020). The PPVT was a significant predictor of vitalist reasoning even though it does not probe knowledge of biological facts specifically (Zaitchik et al., 2014). However, children's executive function scores, precisely cognitive flexibility and inhibition, predicted children's understanding of several central concepts within the vitalist biology (i.e., life, death, and bodily function). The authors suggested that executive functions are involved in the development and use of a complex domain of knowledge.

In the present study, our approach is different. We aim to investigate how variations in children's executive functions contribute to differences in categorization performance, both independently and in comparison to the breadth of their factual knowledge. Our hypothesis suggests that enhanced inhibition of previously activated knowledge when context demands it or better cognitive flexibility (i.e., shifting from a perspective toward another perspective for a given object) may account for variations in categorization development. To examine executive functions in categorization, we use cross-categorization tasks, as they have been hypothesized to require inhibiting previously activated classifications and/or flexibly activating alternative representations (Blaye & Jacques, 2009).

Existing evidence suggests that category knowledge may not be the only factor explaining children's performance in cross-categorization tasks. While no study has directly correlated children's performance in these tasks with independent measures of executive functions, cognitive control is likely involved. For instance, in Nguyen and Murphy (2003), 4- and 7-year-old children were presented with nonconflicting and conflicting triads. Nonconflicting triads consisted of a target food and two choices: a taxonomically or thematically related choice and an unrelated choice. Conflicting triads included a taxonomic choice and a thematic choice simultaneously. Children performed above chance in the nonconflicting triads, indicating sufficient taxonomic and thematic knowledge. However, the 4-year-old group was at chance in conflicting triads, which can be interpreted as no preference for the taxonomic choice over the thematic one or insufficient maturation of cognitive control processes.

To test this idea, Blaye and Jacques (2009) used two kinds of cross-categorization tasks involving 3–6-year-old children. Similarly to Nguyen and Murphy's (2003) nonconflicting trials, children had to associate a target stimulus (e.g., a dog) with a taxonomic choice (i.e., a snail) and a thematic choice (i.e., a kennel) across two separate trials while ignoring two conceptually unrelated stimuli. The objective was for children to correctly select the two associated stimuli presented in each trial. In a second task, the taxonomic and thematic choices (i.e., the snail and the kennel) were presented simultaneously with an unrelated choice. Children had to select the two correct semantic options sequentially. In this second task, children did not have to choose a preferred type of relationship over the other. For the authors, a failure to switch between the semantically related choices would indicate insufficient executive control. While a large majority of children aged 3 and above could cross-categorize successfully in the first task, fewer than half of 3-year-olds and approximately half of 4-year-olds were able to do so in the task involving sequential selection of both taxonomic and thematic choices. The authors interpreted this discrepancy in terms of the development of executive functions, which undergo rapid changes after the age of 4 in assessments of cognitive flexibility such as the Dimensional Change Card Sort (DCCS) task (Diamond, 2013; Zelazo et al., 2013). No assessment of children's cognitive flexibility was conducted, but these findings suggest that executive functions may mediate categorization development (see also Kharitonova et al., 2009; Lagarrigue & Thibaut, 2020; Nguyen & McDermott, 2024; Rabi & Minda, 2014; Simms et al., 2018; Wellman et al., 2001).

So far, we have proposed that categorization and cross-categorization can be influenced differentially by accumulated factual knowledge and executive functions. We now examine individual differences related to children's processing of the conceptual domain of food. As mentioned above, recent evidence suggests that high levels of food neophobia undermine children's categorization and reasoning about food. By considering these individual differences in food neophobia, we aim to shed light on how such characteristics, through accumulated factual knowledge and executive functions, may influence categorization abilities.

Food neophobia refers to the reluctance to eat or even try novel foods (Lafraire et al., 2016; Reilly, 2018). Neophobic reactions are typically observed between the ages of 3 and 6. Their developmental trajectory beyond this period is not well understood (Dovey et al., 2008; Van Tine et al., 2017). Research has shown a negative association between food neophobia and categorization performance in the food domain (Foinant et al., 2022a; Rioux et al., 2016, 2018a). Rioux et al. (2016) conducted a study with 2–6-year-old children using a forced-choice task to assess their ability to discriminate between vegetables and fruits. Their results revealed a negative correlation between children's food neophobia scores and their categorization performance. Similar findings were reported by Rioux et al. (2018a), in a category-based induction task. Neophobic children tend to rely more on perceptual similarities to infer novel properties. For instance, they might generalize a property of a green zucchini to a green banana based on visual resemblance, whereas less neophobic children use taxonomic relationships and generalize to a perceptually dissimilar vegetable, such as an orange carrot. Critically, these conceptual difficulties in neophobic children are independent of their age within the 3–6-year-old range (see also Pickard et al., 2021, 2023, for similar findings in the context of thematic categories).

Food neophobia provides an interesting case of individual characteristics negatively influencing categorization abilities within the food domain. In the present study, we tested whether the mediation of accumulated factual knowledge and executive functions between age and categorization abilities we hypothesized above would also apply between food neophobia and categorization abilities. Indeed, children's neophobic tendencies may limit their exposure to different types of food, thereby reducing opportunities for the development of food-related knowledge (Rioux et al., 2016). However, previous studies have found no significant correlation between food neophobia and semantic organization (Rioux et al., 2018a) or food identification (Pickard et al., 2021). These findings suggest that the negative relationship between food neophobia and categorization in the food domain might also result from other factors than semantic knowledge gaps.

It has been suggested, instead, that the difficulties faced by neophobic children stem from less-developed executive functions (Foinant et al., 2022b). Foinant et al. (2022b) showed that higher levels of food neophobia in children aged 3–6 were associated with lower cognitive flexibility scores, independently of age, while no significant differences were found in terms of inhibition and working memory. Interestingly, consistent with previous results, food neophobia was not found to correlate with accumulated factual knowledge, as assessed using the PPVT vocabulary test. Building upon these findings, we hypothesized that executive functions may serve as a mediating factor in explaining the lower performance of neophobic children in former categorization studies.

The Present Study

In the present study, we adopted an individual differences approach within the selected 3–6 age range to investigate the potential mediating role of accumulated factual knowledge and executive functions in the development of categorization and cross-categorization abilities (i.e., to consider an object as a member of multiple categories; Blaye & Bonthoux, 2001; Blaye et al., 2006; Nguyen & McDermott, 2024).

In a first experiment, children's categorization was assessed with a forced-choice task that was assumed to elicit minimal cognitive load. Children had to sort vegetables and fruits into their respective categories. In the second experiment, we adapted Blaye and Jacques' (2009) double-choice task to test children's ability to cross-categorize the same food according to two different relationships (i.e., taxonomic and thematic) alternatively while ignoring a distractor food.

Accumulated factual knowledge was assessed with the PPVT (Dunn & Dunn, 2007), a receptive vocabulary test that reflects the width of knowledge across a broad range of domains (Bascandziev et al., 2018; Tardiff et al., 2020). Following Miyake et al.'s (2000) model, we focused on the three main executive functions: working memory, inhibition, and cognitive flexibility.

Factual knowledge was hypothesized to be the most important factor explaining age-related effects for categorization and cross-categorization performance since to (cross-)categorize an item into a taxonomic or thematic category, children must have the relevant background knowledge (Nguyen & Murphy, 2003).

However, interindividual differences in accumulated factual knowledge alone might not explain children's performance in a categorization task, especially when the task demands increase. In the latter case, it is likely that the contribution of cognitive monitoring (i.e., executive functions) also increases, as children must coordinate a larger amount of information.

For instance, in the cross-categorization task, children were asked to select two matches for a target stimulus among three options (i.e., the two related options were a taxonomic match and a thematic match, whereas the third option was conceptually unrelated). The two solutions did not share the same conceptual relationship with the target, and the first selection remained in view when the child was looking for the second selection. According to Blaye and Jacques (2009), achieving categorical flexibility requires conceptual knowledge of both kinds of associations and sufficient executive functions, particularly cognitive flexibility, to access and switch between alternative representations, even when they conflict. We also hypothesized that older children might be better at choosing the alternative because they can inhibit the initial, irrelevant relationship more effectively than younger children (see Oakes & Madole, 2003, p. 135).

Beyond exploring how accumulated factual knowledge and executive functions mediate age-related improvements in categorization and cross-categorization abilities, our study aimed to further understand whether these factors also mediate the previously reported negative association between children's food neophobia and these abilities. Building on findings from Foinant et al. (2022b) and Pickard et al. (2023), we hypothesized that cognitive flexibility, compared to factual knowledge, might act as a stronger mediator of the negative influence of food neophobia on categorization performance.

Experiment 1: Superordinate Categorization Task

Participants

Previous research on food categorization tasks with children, incorporating semantic knowledge, reported effect sizes of .510 between age and identification scores and .393 between identification scores and categorization performance (Pickard et al., 2021). To achieve a power of .90 at the standard α error probability of .05, a sample size of 122 children was necessary. A total of 136 children aged 4–6 years were recruited from preschools to participate in the study. Participants who did not complete all cognitive assessment tasks were excluded ($n = 14$). This left a final sample of 122 children (67 girls; age range = 57.0 to 75.1 months; $M_{age} = 67.4$ months; $SD = 4.05$). They were predominantly Caucasian and came from middle-class urban areas. The study was approved by the ethics committee of Lyon University (ref. 2023-02-02-004). All procedures of the study complied with the ethical standards of the 1964 Declaration of Helsinki regarding the treatment of human participants in research. Written informed consent to participate in this study was provided by the participant's legal guardian/next of kin. The participants reserved the right to withdraw from the study without consequences.

Materials—Categorization Task

To assess each child's level of food neophobia, caregivers filled out the Child Food Rejection Scale (CFRS; Rioux et al., 2017). The CFRS displays strong test–retest reliability (intraclass correlation of 0.90 over a 1-month interval) and convergent validity (0.81 correlation with the Food Attitude Survey). The CFRS is a heteroevaluation scale measuring 2–7-year-old children's food neophobia on a six-item scale. On 5 points (*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"). Higher scores indicate higher levels of food neophobia (scores could range from 6 to 30, $M = 15.2$, $SD = 4.89$).

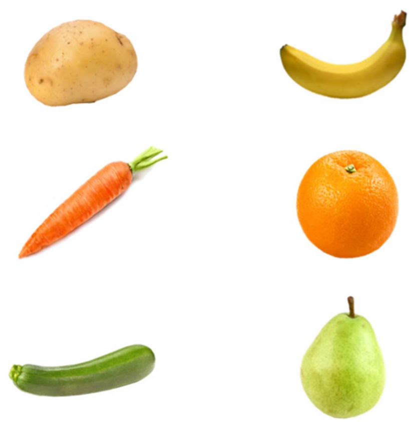
Children were tested with a set of 34 color photographs from two categories: vegetables ($n = 16$) and others ($n = 18$, 10 fruits, and eight utensils). The set of "others" stimuli was composed of items coming from a taxonomical category close to vegetables, that is, fruits, and items from a semantically related category, that is, utensils. The utensils were meant to be control stimuli. We chose kitchen utensils as controls because, despite the fact they are clear nonfoods, they are semantically related to the food domain. Children who miscategorized two or more utensils as vegetables were excluded ($n = 0$). Each picture was printed on a laminated card measuring 14.8 cm × 21 cm (see Figure 1 for an example of the stimuli used in the experiment).

The images were obtained from databases (Blechert et al., 2014; Foroni et al., 2013) and copyright-free online sources.

Procedure

Children were tested individually in their preschool. They sat at a table, with the experimenter at their side. On the table, there were two opaque mailboxes. Opaque mailboxes were favored to prevent children from using comparison strategies. The experimenter explained to the child that the rule of the game was to sort the pictures into the two mailboxes. First, the children were trained with 16 demonstration trials and were told (in French), "I'm going to show you pictures of different things. I want you to help me put the animal pictures ($n = 8$) all in the same box, and put the other pictures, that are not animals (tools, $n = 6$, and flowers, $n = 2$) in the other box." During the training, the experimenter provided feedback. Following training, children were told, "Now, I want you to help me put the pictures of the vegetables in the same box, and put the other pictures, that are not vegetables in the other box." No feedback was provided. Stimuli were presented in a randomized

Figure 1
Example of the Stimuli Used in Experiment 1



Note. See the online article for the color version of this figure.

order, which differed for each participant. For each item, a score of 1 was given when children successfully placed it in the corresponding mailbox and a 0 score when they did not place it properly.

The assessment of children's accumulated factual knowledge and executive functions took place in two different sessions of 20 min each, with two tasks per session. The order of the tasks was random. We assessed accumulated factual knowledge via a standard vocabulary test. We assessed the three components of executive functions described by Miyake et al. (2000), which are working memory, inhibition, and cognitive flexibility. For the working memory and flexibility tasks, we adapted the corresponding tasks from the National Institutes of Health Toolbox battery (NIH Toolbox Cognition Battery). 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 touchscreen computer. All tests have been standardized for preschool-aged children (Catale & Meulemans, 2009; Tulsky et al., 2013; Zelazo et al., 2013).

We assessed children's *accumulated factual knowledge* with the Échelle du vocabulaire en images de Peabody, a French adaptation of the PPVT (Dunn & Dunn, 2007). The PPVT has strong test–retest reliability (intraclass correlation of 0.92 over a 1-month interval) and established convergent validity (0.91 correlation with the Wechsler Intelligence Scale for Children-III Verbal IQ). The test is adapted for children aged 2½ 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. This vocabulary test serves as a reliable proxy for knowledge base, supported by its strong correlations with other measures of factual knowledge (Bascandziev et al., 2018; Tardiff et al., 2020) and its nonspecific focus on a specific domain. Scores are based on the number of correct responses (the maximum score is 228).

The List Sorting Working Memory Test assesses children's *working memory* as part of the NIH Toolbox Cognition Battery (Tulsky et al., 2014). This test has strong test–retest reliability (intraclass correlation of 0.77 over a 7–21-day interval) and convergent validity (0.57 correlation with the Wechsler Adult Intelligence Scale-IV Letter Number Sequence). It is a computerized sequencing task requiring verbally recalling items that are presented visually and auditorily according to a given rule (e.g., from the smallest to the biggest). The number of items starts with two stimuli, up to five, and the task is stopped after two consecutive errors with the same number of items. The sorting test score is the number of sequences correctly recalled in each list. The maximum score is 16.

Inhibition was assessed with the Real Animal Size Test (Catale & Meulemans, 2009), a nonalphabetic Stroop-like task showing high test–retest reliability for both congruent and incongruent conditions. Children were asked to categorize pictures of animals based on 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). All trials with reaction times (RTs) inferior to 100 ms and superior to 10,000 ms, or two standard deviations from the mean, were considered outliers and discarded from computing each child's accuracy.

Cognitive flexibility was assessed with the DCCS, a rule-shifting task from the NIH Toolbox Cognition Battery (Zelazo et al., 2013). The DCCS has strong test–retest reliability (intraclass correlation of 0.79 over a 2-week interval) and moderate convergent validity (0.69 correlation with Wechsler Preschool and Primary Scale of Intelligence-III Block Design in 3–6-year-olds). 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 rabbit and blue boat), first according to one dimension (e.g., color), and then according to the other (e.g., shape). Accuracy ranged from 0 to 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 reaction times (RTs) on correct infrequent trials in the mixed-phase following a log (base 10) transformation (see Zelazo et al., 2013, for computation details). The maximum flexibility score is 10 when accuracy is 100% and RTs are 500 ms.

Transparency and Openness

We report all data exclusions and measures in the study. The data for the present study are publicly available at https://osf.io/fdx2z/. The study's design and its analysis were not preregistered. All analyses were run using R Version 4.2.1 (R Core Team, 2022). Additional online materials are available at https://osf.io/fdx2z/. These supplemental materials include (1) the list and (2) the 50 color photographs used in the training ($n = 16$) and test phase ($n = 34$) of the categorization task; (3) deidentified data; and (4) mediation analyses code in R.

Results

Preliminary Analyses

Descriptive statistics for age, categorization performance, factual knowledge, executive functions, and food neophobia scores are presented in Table 1. We controlled for a moderating effect of gender using independent samples *t* tests with a Bonferroni-adjusted α level of $p \leq .005$. Children did not differ according to their gender in age, or on any of the measures.

Associations between variables were examined using Pearson's correlation coefficients. All zero-order correlations are presented in Table 2. Not surprisingly, analyses indicate that age was positively

Table 1
Descriptive Statistics for Experiment 1

Variable	Children (n = 122) M (SD)	Range (possible minimum–maximum score)	Comparison between girl and boy t	Cohen's d
Age (in months)	67.4 (4.05)	57.0–75.1	−0.49	−0.09
Categorization performance	0.84 (0.12)	0.50–1 (0–1)	0.87	0.11
Factual knowledge	75.5 (20.3)	18–132 (0–228)	−0.47	−0.09
Working memory	6.10 (2.18)	1–14 (0–16)	0.03	0.01
Inhibition	0.90 (0.13)	0.47–1 (0–1)	0.38	0.07
Cognitive flexibility	5.18 (1.11)	2.50–7.21 (0–10)	2.09	0.38
Food neophobia	15.2 (4.89)	6–29 (6–30)	−0.76	−0.14

correlated with categorization performance, factual knowledge, and the three executive functions ($p < .05$). Note that age was not associated with food neophobia ($r = .009$, $p = .922$). Food neophobia was negatively correlated with categorization performance, working memory, and cognitive flexibility ($p < .05$). Factual knowledge and the three executive functions were all positively correlated with each other ($p < .05$). The most important results were that categorization performance was positively associated with factual knowledge, working memory, and cognitive flexibility ($p < .001$).

Mediation Analyses

Tests of mediation were conducted according to Hayes's (2022) method. A first model tested whether factual knowledge and executive functions mediate the relationship between age and categorization performance. A second model tested whether factual knowledge and executive functions mediate the relationship between food neophobia and categorization performance. Mediation analyses were conducted using PROCESS Version 4 (Hayes, 2022). This method calculates percentile-corrected 95% confidence intervals (CIs) using bootstrapping with 5,000 resamples. The outcome of the test could be considered significant if the 95% confidence interval of computed statistics did not include zero. The percentile bootstrap confidence interval does not assume a symmetrical sampling distribution of the indirect effect and possesses adequate control over the Type I error rate (Hayes, 2022). It does not inflate the risk of Type II error rates either (Hayes & Scharkow, 2013). All reported coefficients are standardized. As an indicator of effect size, R^2 is reported for the total model, showing how much variance in categorization performance is explained by the combination of either age or food neophobia and the four mediators: factual knowledge, working memory, inhibition, and cognitive flexibility.

We first estimated the relationship between age and categorization performance. The direct effect of age (i.e., the effect of age on categorization performance independently of the influence of the mediators) did not remain significant (β = −.003, 95% CI [−.174, .168]). As shown by Figure 2, there were indirect effects of factual knowledge (β = .100, 95% CI [.026, .191]), working memory (β = .061, 95% CI [.004, .132]), and cognitive flexibility (β = .069, 95% CI [.014, .140]). In addition, results showed that the size of these indirect paths did not differ from one another (for all pairwise comparisons, 95% CIs straddled zero). This model accounted for 29.3% of the variance in categorization performance ($R^2 = .293$, $F(5, 116) = 9.62$, $p < .001$).

As for our second main purpose, looking at the relationship between food neophobia and categorization performance, the direct effect of food neophobia remained significant (β = −.180, 95% CI [−.339, −.020]), even after including the mediators. There was only an indirect effect of cognitive flexibility (β = −.064, 95% CI [−.130, −.009]). This model accounted for 32.2% of the variance in categorization performance, $R^2 = .322$, $F(5, 116) = 11.03$, $p < .001$.

Experiment 1: Discussion

The first experiment investigated the relationships between age, food neophobia, accumulated factual knowledge, executive functions, and categorization performance using a forced-choice task. Age positively influenced categorization performance, fully mediated by factual knowledge and executive functions. Notably, indirect effects were observed through factual knowledge, working memory, and cognitive flexibility, with all three mediators playing comparable roles.

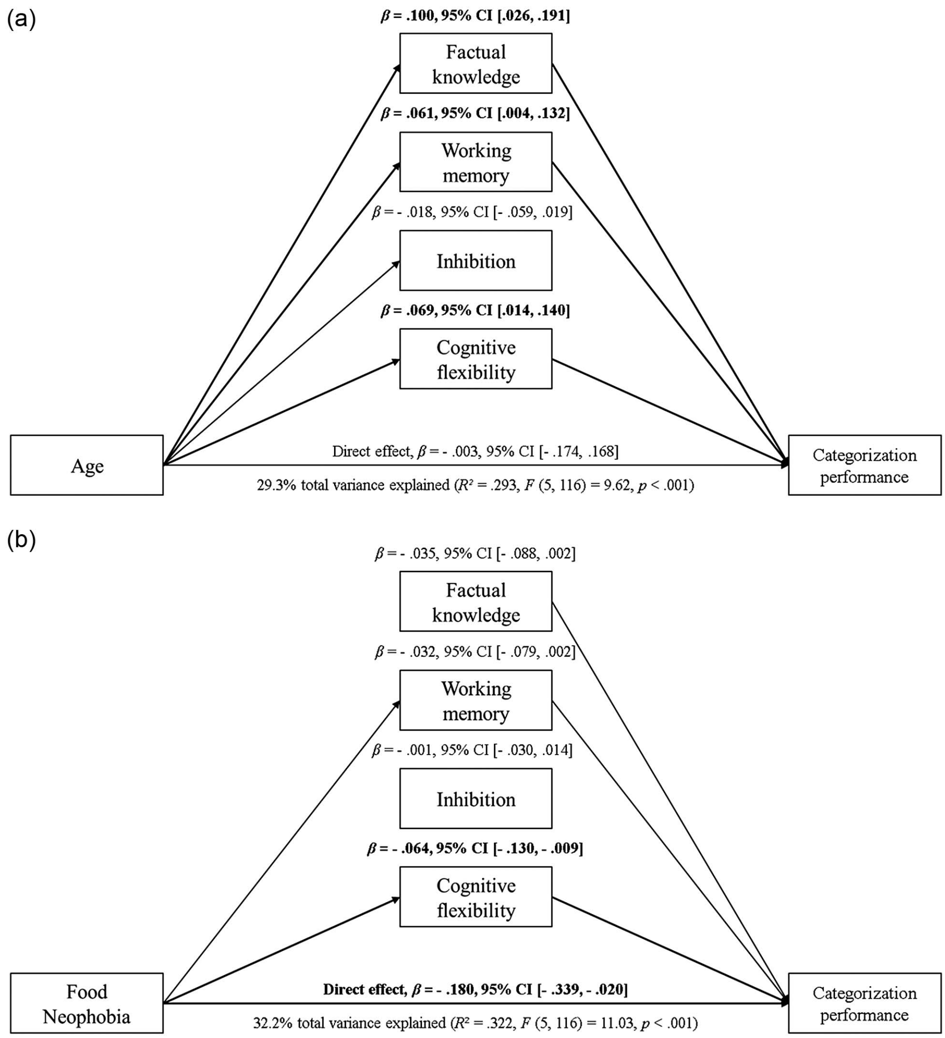
Table 2
Zero-Order Pearson's Correlations Between Experiment 1 Variables

Variable	Age	Categorization performance	Factual knowledge	Working memory	Inhibition	Cognitive flexibility
Categorization performance	$r = .209^{*}$					
Factual knowledge	$r = .383^{***}$	$r = .425^{***}$				
Working memory	$r = .318^{***}$	$r = .386^{***}$	$r = .466^{***}$			
Inhibition	$r = .185^{*}$	$r = .068$	$r = .265^{**}$	$r = .213^{*}$		
Cognitive flexibility	$r = .250^{**}$	$r = .416^{***}$	$r = .367^{***}$	$r = .342^{***}$	$r = .210^{*}$	
Food neophobia	$r = .009$	$r = -.312^{***}$	$r = -.135$	$r = -.188^{*}$	$r = .013$	$r = -.280^{**}$

$^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Figure 2

Mediation Analyses on Categorization Performance With Standardized Regression Coefficients and Overall R^2 Values as Effect Sizes



Note. Analyses illustrate the direct and indirect effects of age (a) and food neophobia (b) on categorization performance. Direct and indirect effects that were statistically significant are presented in bold. Arrows are only present for statistically significant effects. CI = confidence interval.

Food neophobia directly negatively impacted categorization performance, with cognitive flexibility serving as an indirect mediator. These intriguing results suggest that even with a simple task, the ability to conform to different instructions (i.e., if a vegetable, then; and if not a vegetable, then), retain them in memory, and switch between them is linked to executive functions. Hence, executive functions played a significant role alongside knowledge, despite the task's low cognitive demands. Additionally, these findings highlight the importance of considering individual differences in specific conceptual domains.

Experiment 2: Cross-Categorization Task

The previous findings have shed light on the importance of accumulated factual knowledge and executive functions in the development of categorization abilities. However, the use of a forced-choice paradigm in the previous experiment limited our understanding of how executive functions specifically contribute to performance. To address this, we turned to the double-choice cross-categorization task introduced by Blaye and Jacques (2009). This task allows us to investigate how both accumulated factual knowledge and executive functions influence children's ability to sequentially associate a target item with two different choices: a taxonomic choice and a thematic choice.

In this task, the initial selection reflects the participants' most salient choice and requires less cognitive monitoring. In contrast, the subsequent selection involves switching from one conceptual relationship (e.g., taxonomic) to another (i.e., thematic) in the presence of the previous choice. We hypothesized that this switch necessitates cognitive processes such as inhibition or cognitive flexibility, or perhaps both.

Considering the first selection, we predicted that only accumulated factual knowledge would mediate the relationship between age and categorization performance. As for food neophobia, the first selection should confirm Experiment 1 that food neophobia influences categorization performance even when less executive control is required.

However, for the second selection, involving to subsequentially switch between both taxonomic and thematic options, we hypothesize that cognitive flexibility (and potentially inhibition) may mediate the relationship between age and categorization performance. Given that cognitive flexibility is likely involved, we further hypothesized that it would mediate the relationship between food neophobia and categorization performance.

Participants

Participants were 100 children (55 girls and 45 boys; age range = 37.2–75.2 months; M_{age} = 61.1; *SD* = 9.29). 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. None of these children participated in Experiment 1.

Materials—Categorization Task

As in the previous study, the caregivers filled out the CFRS to evaluate their child's food neophobia (*M* = 15.1, *SD* = 5.64).

We constructed 11 stimuli made of four color photographs of real food. Each stimulus was presented on an A4 sheet displayed horizontally with the target (e.g., a lemon) at the top and centered and three tests (three foods) on the same line below the target (see Figure 3). Among these three tests, one was a superordinate taxonomic choice (e.g., another fruit, a pear), another was a thematic option (e.g., codfish), and the remaining one was an unrelated food (e.g., a natural-flavored yogurt). The spatial location (left, middle, or right) of the three types of tests (taxonomic, thematic, or unrelated) was counterbalanced. Two additional nonfood stimuli were used in demonstration trials.

Three independent groups of 20 adults participated in rating tasks to ensure that each item in the three types of test items belonged to the test type it was hypothesized to belong to, which is either taxonomically related, thematically related, or unrelated. We also tested whether the three tests were perceptually dissimilar to the target. Each group was shown 16 stimuli in the same format as in the actual task (a target and three potential tests) in a counterbalanced order. The first group was asked to rate on a 7-point Likert-like scale to what extent each test belonged to the same taxonomic category as the target. The second group was asked to rate on a 7-point Likert-like scale to what extent each test was frequently associated in the same context with the target (i.e., whether the target and the test often appear *together*). The third group rated perceptual similarity between each test and the target on a 7-point Likert-like scale. Descriptive statistics can be found in Table 3. We only kept stimuli with ratings significantly lower than 4 for perceptual similarity. For taxonomic ratings, we kept stimuli with taxonomic ratings significantly lower than 4 for each nontaxonomic choice and a taxonomic rating significantly higher than 4 for the taxonomic choice. For thematic ratings, we kept stimuli with thematic ratings significantly lower than 4 for each nonthematic choice and thematic ratings significantly higher than 4 for the thematic choice.

Procedure

We tested children individually in their school. The categorization task began with two nonfood training trials. In each trial, children were asked to select two tests for each target. For their first selection, children were told (in French), "Look at this (the experimenter pointing to the target). Can you show me, among these three (the experimenter pointing the potential tests), the one that goes best with

Figure 3
Example of a Stimulus

Note. The target corresponds to the lemon, the taxonomic choice to the pear, the thematic choice to the codfish, and the unrelated choice to the natural-flavored yogurt. See the online article for the color version of this figure.

Table 3
Mean Perceptual, Taxonomic, and Thematic Ratings for the Three Types of Tests of 16 Stimuli

	Three types of test		
Rating	Taxonomic	Thematic	Unrelated
Perceptual	2.13 (0.60)	2.11 (0.82)	1.81 (0.47)
Taxonomic	5.58 (0.91)	2.81 (1.46)	1.60 (0.55)
Thematic	3.32 (1.10)	5.96 (0.97)	1.59 (0.57)

Note. Standard deviation in brackets.

this one (pointing again to the target)? To show me, place this coin on top of the one you chose."

For their second selection, they were told, "Now there are only two left. Can you show me out of these two (pointing the choices without coin), which one goes better with this one (pointing to the target)? Here is another coin to indicate your choice." If children selected the unrelated test for either selection in the demonstration trials, they received corrective feedback, and the coin was moved to the correct choice. The order of the two demonstration trials was counterbalanced across participants. After the two demonstration trials, 11 test trials were presented with no corrective feedback. For the first selection, a score of 1 was given when participants successfully selected one of the two correct tests (i.e., taxonomic or thematic), and a score of 0 was given when they selected the unrelated food. We then assigned each participant a mean first selection accuracy score and a mean double selections accuracy score that was dependent on performance on the first selection (i.e., the proportion of trials for which participants made two correct selections).

The procedure for assessing children's factual knowledge, working memory, inhibition, and cognitive flexibility was the same as in the first experiment. We respectively used the Échelle du vocabulaire en images de Peabody (Dunn & Dunn, 2007), the List Sorting (Tulsky et al., 2014), the Real Animal Size Test (Catale & Meulemans, 2009), and the DCCS (Zelazo et al., 2013).

Transparency and Openness

We report all data exclusions and measures in the study. The data for the present study are publicly available at https://osf.io/fdx2z/. The study's design and its analysis were not preregistered. All analyses were run using R Version 4.2.1 (R Core Team, 2022). Additional online materials are available at https://osf.io/fdx2z/. These supplemental materials include (1) the 13 stimuli made of four color photographs used in the training ($n = 2$) and test phase ($n = 11$) of the cross-categorization task, (2) the ratings of the stimuli used in the test phase, (3) deidentified data, and (4) mediation analyses code in R.

Results

Preliminary Analyses

A control group of adults ($n = 40$) also performed the categorization task to ensure that our taxonomic and thematic tests would indeed be selected appropriately. These participants were university students from a French university. Adults' performance on the double selections was significantly above 0.33 (double selections scores are dependent on first selection performance; $p = .67$ for the first selection and $p = .50$ for the second selection, thus, $p = .33$ for both; $M = 0.94$, $SD = 0.07$; $t = 53.0$, $p < .001$, $d = 8.38$).

For children's data, we followed the same statistical analysis strategy as in the first experiment on, respectively, their first selection and double selections performances. Descriptive statistics for age, first selection, double selections, factual knowledge, executive functions, and food neophobia scores are presented in Table 4. We controlled for a moderating effect of sex using independent samples t tests with a Bonferroni-adjusted α level of $p \leq .005$. Children did not differ according to their sex in age or on any of the measures.

Associations between variables were examined using Pearson's correlation coefficients. All zero-order correlations are presented in Table 5. Analyses indicated that age was positively correlated with first and double selections performance, factual knowledge, and the three executive functions ($p < .05$). Age was not associated with food neophobia ($r = -.068$, $p = .503$). Food neophobia was negatively correlated with first and double selections performance, inhibition, and cognitive flexibility ($p < .01$). Factual knowledge and the three executive functions were all positively correlated with each other ($p < .05$). More interestingly, first selection performance was positively associated with factual knowledge, working memory, and cognitive flexibility ($p < .05$). Double selections performance was positively associated with factual knowledge, inhibition, and cognitive flexibility ($p < .05$).

Mediation Analyses

As in Experiment 1, tests of mediation were conducted according to Hayes' (2022) method, using PROCESS Version 4. We first

Table 4
Descriptive Statistics for Experiment 2

Variable	Children ($n = 100$) M (SD)	Range (possible minimum–maximum score)	Comparison between girl and boy t	Cohen's d
Age (in months)	61.1 (9.39)	37.2 to 75.2	−0.44	−0.09
First selection	0.88 (0.11)	0.55–1 (0–1)	−0.55	−0.11
Double selections	0.64 (0.18)	0.27–1 (0–1)	−0.85	−0.17
Factual knowledge	72.6 (17.6)	18–114 (0–228)	−0.26	−0.05
Working memory	5.89 (2.04)	1–12 (0–16)	0.59	0.12
Inhibition	0.90 (0.13)	0.41–1 (0–1)	0.07	0.01
Cognitive flexibility	4.87 (1.23)	1.75–7.36 (0–10)	2.06	0.41
Food neophobia	15.2 (5.50)	6–29 (6–30)	−1.12	−0.22

Table 5
Zero-Order Pearson's Correlations Between Experiment 2 Variables

Variable	Age	First selection	Double selections	Factual knowledge	Working memory	Inhibition	Cognitive flexibility
First selection	$r = .349^{***}$						
Double selections	$r = .379^{***}$	$r = .539^{***}$					
Factual knowledge	$r = .607^{***}$	$r = .465^{***}$	$r = .487^{***}$				
Working memory	$r = .246^{*}$	$r = .205^{*}$	$r = .170$	$r = .369^{***}$			
Inhibition	$r = .243^{*}$	$r = .112$	$r = .198^{*}$	$r = .277^{**}$	$r = .174$		
Cognitive flexibility	$r = .306^{**}$	$r = .272^{**}$	$r = .461^{***}$	$r = .501^{***}$	$r = .314^{***}$	$r = .368^{***}$	
Food neophobia	$r = -.068$	$r = -.263^{**}$	$r = -.357^{***}$	$r = -.180$	$r = -.064$	$r = -.293^{**}$	$r = -.447^{***}$

$^{*} p < .05.$ $^{**} p < .01.$ $^{***} p < .001.$

tested whether factual knowledge and executive functions mediate the relationship between age or food neophobia and first selection performance. Then, we tested whether factual knowledge and executive functions mediate the relationship between age or food neophobia and double selections performance. All reported coefficients are standardized. As an indicator of effect size, R^2 is reported for the total model, showing how much variance in first and double selections performance is explained by the combination of either age or food neophobia and the four mediators: factual knowledge, working memory, inhibition, and cognitive flexibility.

The relationship between age and first selection performance was the first model to be estimated. The direct effect (i.e., the effect of age on first selection performance independently of the influence of the mediators) did not remain significant (β = .109, 95% CI [−.117, .338]). As can be seen in Figure 4, there was only an indirect effect of factual knowledge (β = .224, 95% CI [.027, .380]). This model accounted for 22.8% of the variance in first selection performance, $R^2 = .228$, $F(5, 94) = 5.55$, $p < .001$.

For the relationship between food neophobia and first selection performance, the direct effect remained significant (β = −.215, 95% CI [−.418, −.026]), and there was no indirect effect. This model accounted for 25.7% of the variance in first selection performance, $R^2 = .257$, $F(5, 94) = 6.49$, $p < .001$.

Following this, the relationship between age and double selections performance was estimated. The direct effect of age did not remain significant (β = .134, 95% CI [−.080, .349]). As can be seen in Figure 5, there were indirect effects of factual knowledge (β = .169, 95% CI [.001, .339]) and cognitive flexibility (β = .093, 95% CI [.024, .182]). In addition, a pairwise comparison showed that the size of these indirect paths did not differ from one another (β = .077, 95% CI [−.143, .280]). This model accounted for 31.4% of the variance in double selections performance, $R^2 = .314$, $F(5, 94) = 8.60$, $p < .001$.

For the relationship between food neophobia and double selections performance, the direct effect of food neophobia remained significant (β = −.210, 95% CI [−.402, −.022]). There was only an indirect effect of cognitive flexibility (β = −.092, 95% CI [−.197, −.001]). This model accounted for 33.7% of the variance in double selections performance, $R^2 = .337$, $F(5, 94) = 9.56$, $p < .001$.

Experiment 2: Discussion

The second experiment used a double-choice cross-categorization task to investigate the relationships between age, food neophobia, accumulated factual knowledge, executive functions, and categorization performance.

Mediation analyses revealed that age influenced first selection performance through its indirect effect on factual knowledge. This indicates that age influences initial categorization performance via children's growing factual knowledge of the world. Similarly, age influenced double selections performance through its mediation by factual knowledge and cognitive flexibility. Cognitive flexibility played a crucial role in children's ability to switch between taxonomic and thematic categories. On the other hand, food neophobia had a direct effect on categorization performance for both first and double selections. This suggests that food neophobia directly impacts categorization performance, even when cognitive demands are lower. Additionally, cognitive flexibility acted as an indirect mediator in the relationship between food neophobia and double selections performance.

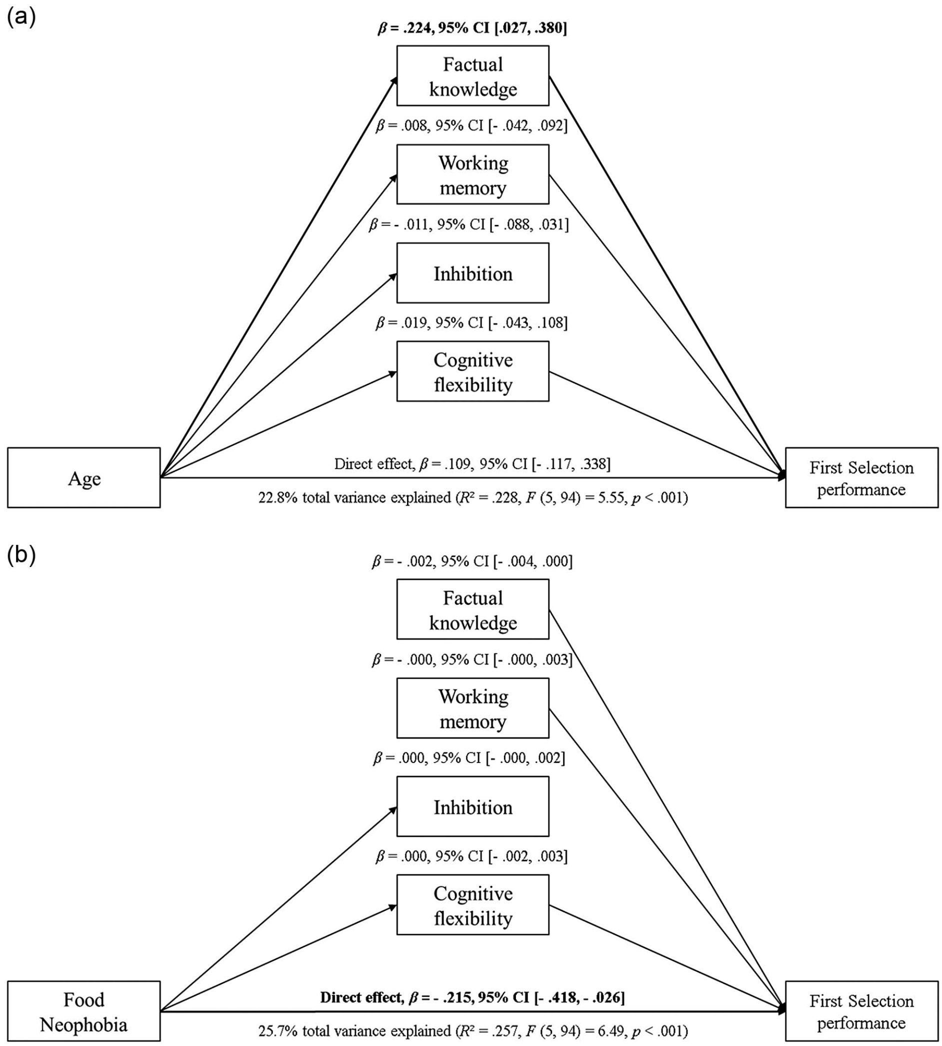
General Discussion

This correlational study examined the roles of accumulated factual knowledge (assessed through a receptive vocabulary test) and executive functions (i.e., working memory, inhibition, and cognitive flexibility) in (a) explaining age-related changes in categorization abilities during the preschool years and (b) investigating how child-characteristic food neophobia influences categorization performance. Experiment 1 was a forced-choice categorization task that was hypothesized to minimize cognitive load and not involve executive monitoring. Experiment 2 used a double-choice cross-categorization task. Children had to make a second selection after their initial choice, requiring a shift in their representation (e.g., from taxonomic to thematic).

Given extensive research demonstrating improvements in categorization performance during early childhood (e.g., Gelman & Markman, 1986; Nazzi & Gopnik, 2001; Nguyen & Murphy, 2003; Rioux et al., 2016; Rosch et al., 1976) and the established role of category-based tasks in assessing conceptual development (Gelman, 2003; Keil, 1992; Murphy, 2002; Sloutsky, 2010), we predicted that accumulated factual knowledge would best predict performance improvements with age in both tasks. Additionally, we hypothesized that a cognitively demanding task like cross-categorization would draw on executive functions, in particular cognitive flexibility and inhibition, further explaining age-related differences.

As expected, both tasks showed significant age-related improvements in performance, with factual knowledge mediating the effect

Figure 4
Mediation Analyses on First Selection Performance With Standardized Regression Coefficients and Overall R^2 Values as Effect Sizes



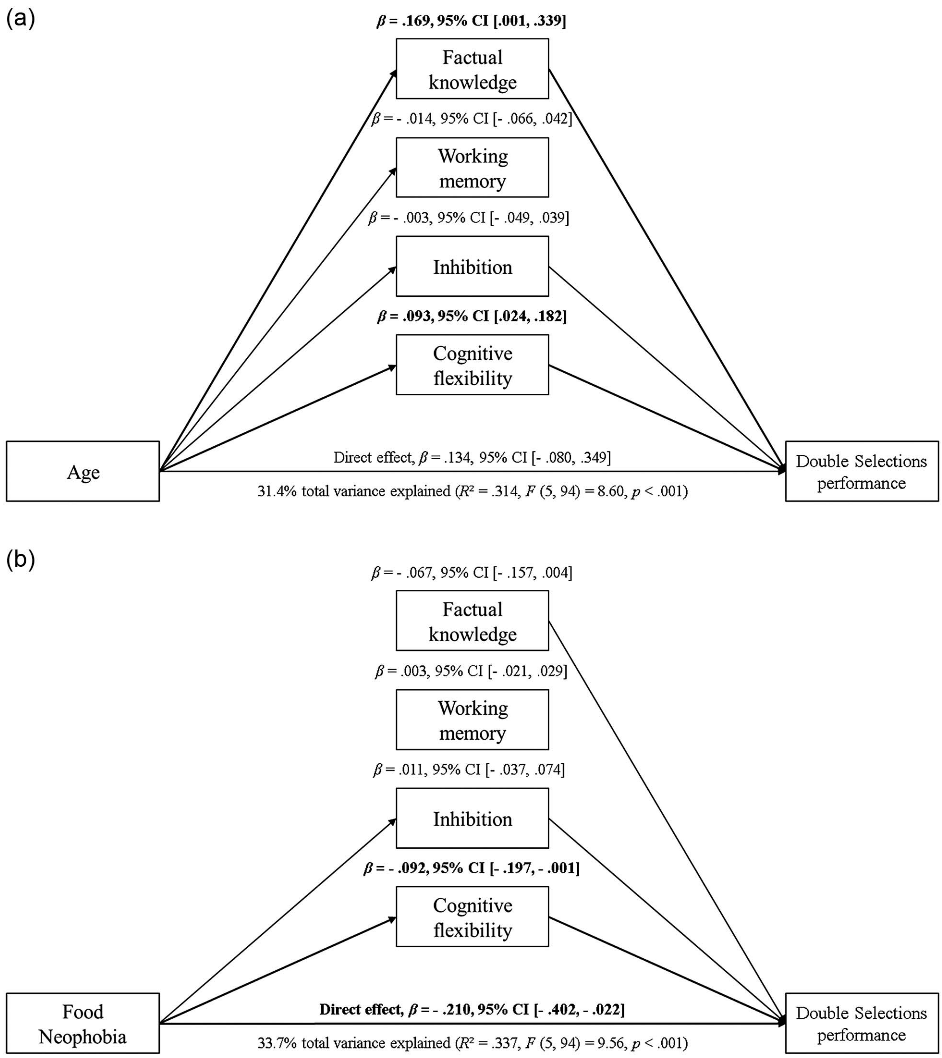
Note. Analyses illustrate the direct and indirect effects of age (a) and food neophobia (b) on first selection performance. Direct and indirect effects that were statistically significant are presented in bold. Arrows are only present for statistically significant effects. CI = confidence interval.

of age on categorization performance. This aligns with the notion that an expanding world knowledge base fosters the development of a semantic network. This, in turn, makes it easier to establish new connections between seemingly unrelated items, which supports finer distinctions within initially undifferentiated or fuzzy concepts and finer categorization (for discussion, see Galotti et al., 2022; Gelman, 2003; Gentner & Hoyos, 2017; Keil, 1992; Murphy, 2002; Oakes & Madole, 2003).

However, our results also reveal a significant effect of executive functions on the development of categorization abilities. We discuss Experiment 2 first, then turn to Experiment 1. In Experiment 2, children's initial selection was solely mediated by factual knowledge. Indeed, we hypothesized that this task would require minimal cognitive effort, as children *simply* needed to identify one conceptual relationship (either taxonomic or thematic) between the target and one of the three options. Indeed, as long as they identified at least one relationship between the target and the options, monitoring constraints were likely minimal. Either the relationship between the target and one of the options was obvious or easily discovered (recall that performance was close to 90% for the first selection). In contrast, the second selection required a switch toward a different conceptual relationship and was significantly explained by both factual knowledge and cognitive flexibility, equally mediating age-related improvements. These findings support our main hypothesis that cognitive flexibility plays a significant role alongside factual knowledge in cross-categorization (see also Blaye & Jacques, 2009). Finding the first solution activates a conceptual relationship. This activation involves highlighting a subset of features common to both

Figure 5

Mediation Analyses on Double Selections Performance With Standardized Regression Coefficients and Overall R^2 Values as Effect Sizes



Note. Analyses illustrate the direct and indirect effects of age (a) and food neophobia (b) on double selections performance. Direct and indirect effects that were statistically significant are presented in bold. Arrows are only present for statistically significant effects. CI = confidence interval.

concepts (or aligning the two representations along these common features; Markman & Gentner, 1993). Identifying the second solution likely requires redescribing the target item from another point of view to conceptually align it with the other conceptually related option. In summary, our study demonstrates that both accumulated factual knowledge and cognitive flexibility jointly contribute to cross-categorization, whereas identifying a single conceptual relationship relies more on the amount of factual knowledge.

Contrary to our hypothesis, Experiment 1 revealed that executive functions were also involved. Accumulated factual knowledge was not the sole mediator of the age-related improvements in what was expected to be a "basic" categorization task. Working memory and cognitive flexibility contributed similarly to the effect of age on categorization performance. Working memory may have been required to keep track of which box corresponded to vegetables and which box corresponded to "other items," in essence, the relation between each spatial location and the corresponding category information, or to refresh this representation (see Logie et al., 2020, for an extensive presentation of models on working memory). Moreover, given that vegetables and fruits are potentially overlapping categories (Rioux et al., 2016), a systematic analysis of the items' features before making a decision is likely to be necessary, especially for less typical items. Although our experiment was not designed to explore this question, it is interesting to note that categorization tasks used for testing category knowledge or representation can involve cognitive monitoring. Only the first choice in Experiment 2 was immune to these influences, most likely because it only requested a matching of activated representations.

Our second main objective was, with the same correlational approach, to assess whether the same cognitive factors account for the differences in categorization associated with food neophobia that have been documented by recent studies (see introduction, e.g., Pickard et al., 2023; Rioux et al., 2016).

Recall that the distribution of food neophobia scores in our samples was independent of age, allowing us to assess the role of neophobia independently of age influences. Both experiments revealed that cognitive flexibility partially mediated the negative relationship between food neophobia and categorization performance, whereas other factors we controlled for did not. Food neophobia undermined categorization development (or food neophilia stimulated it) through its association with cognitive flexibility. However, in both experiments, the direct association between food neophobia and categorization remained significant. Specifically, in Experiment 2, food neophobia negatively affected children's initial selection performance, independently of cognitive flexibility. One candidate explanation raised by previous studies (e.g., Pickard et al., 2021; Rioux et al., 2016) is that a lack of conceptual knowledge contributes to neophobic children's performance.

Accordingly, compared to neophilic children, neophobic children build a less comprehensive food knowledge base due to reduced exposure to novel foods. Since food knowledge is a specific domain of knowledge, a deficit in food would not necessarily extend to accumulated factual knowledge of the world (see Foinant et al., 2022a, for a discussion). Under this interpretation, it is possible that nonspecific factual knowledge did not mediate the relation between food rejection and categorization performance, but that food knowledge would be a more specific mediator. However, former studies did not reveal associations between neophobia scores and level of food knowledge, measured with a food identification task (Pickard et al., 2021) and a semantic space task (Fisher et al., 2015), where children were asked to help organize groceries of fruits and vegetables by placing food items similar in kinds close together in a shopping trolley (Rioux et al., 2018a).

Our data are compatible with a novel interpretation of neophobia-based categorization difficulties. Rather than a lack of knowledge, or difficulties to inhibit irrelevant representations, or inhibit fears elicited by novel foods, or deficits in working memory, what the present data suggest is that neophobic children are less able to flexibly redescribe novel foods or novel instances of familiar foods (like when they refuse a broken instance of a favorite biscuit, or more broadly, when they refuse to "see" novel foods as something to eat; Harris, 2018). This is consistent with the overly rigid eating behaviors that characterize neophobia (Williams et al., 2005). This also aligns with similar patterns of rigidity and a lack of cognitive flexibility found in other populations (Roberts et al., 2007; Twachtman-Reilly et al., 2008). Under this interpretation, the influence of cognitive flexibility could follow a direct and indirect path. Children with lower cognitive flexibility might struggle to interpret novel foods within the context of their existing knowledge. Indirectly, reduced flexibility could hinder neophobic children's ability to classify new foods within different food categorization systems, either taxonomically or thematically. Over time, this could lead to a less developed cross-categorization system compared to their more neophilic peers. More generally, this reasoning could potentially apply to children lacking cognitive flexibility but not exhibiting neophobic behaviors, as the link between cognitive flexibility and categorization might exist independently of age and neophobia (Nguyen & McDermott, 2024).

Limitations and Perspectives

Our study explored the food domain and did not consider other conceptual domains. Indeed, we chose food because it is a central domain that is highly relevant to children's lives and thinking (Birch et al., 1999) and is important for their understanding of health and illness (Rozin, 1990; Thibaut et al., 2020). In addition, food has a complex structure, being both taxonomically and thematically organized (Ross & Murphy, 1999). This dual organization makes it ideal for studying children's cross-categorization, as they are familiar with both types of conceptual knowledge (Nguyen & Murphy, 2003). As such, it reveals children's categorization abilities and the underlying mechanisms of their development. However, exploring other conceptual domains is important to assess the generalizability of our findings. Similar results across domains would raise a key theoretical question regarding the nature of food neophobia: Is it domain-specific or domain-general? Recent evidence from our laboratory suggests that children's food neophobia might extend to other domains as well.

A limitation of the present study is its exclusive reliance on forced-choice paradigms. Future research should explore whether our findings regarding the manipulated cognitive factors generalize to other paradigms, such as category learning (Sloutsky & Fisher, 2004), inductive reasoning (Gelman & Markman, 1986), or analogy tasks (Thibaut et al., 2010). These paradigms assess different aspects of category-based abilities and might yield distinct results. For example, while our cross-categorization task emphasized the importance of cognitive flexibility, working memory has been suggested to be involved in learning abstract categories (Sloutsky, 2018), inductive inferences (Fisher et al., 2015), and analogical reasoning (Simms et al., 2018). Investigating potential differences in the underlying cognitive factors involved in the development of various category-based abilities would be a valuable avenue for future research.

Additionally, we did not gather demographic information from the participants, such as race/ethnicity and socioeconomic status. The preschool locations suggest a predominantly Caucasian and middle-class urban sample. Thus, we recognize that the results and conclusions may be limited to this sample and might not generalize to the wider population. Furthermore, the Échelle du vocabulaire en images de Peabody includes culturally influenced items, and Experiment 2's thematic associations reflect typical French perspectives. Future studies should address this limitation by collecting individual-level demographic data and comparing participants from diverse cultures.

Finally, a limitation of this study is that it only looked at unidirectional relationships, that is, how accumulated factual knowledge and executive functions contribute to age-related improvements in children's categorization abilities. Given our goal, we did not examine the reverse influence of categorization performance on the effect of age on factual knowledge and executive functions. Future longitudinal research should address this gap to build a more comprehensive model of the interrelationships among categorization abilities, factual knowledge, and executive functions. Additionally, future studies could consider incorporating other potentially relevant cognitive factors into the model, such as attention (Deng & Sloutsky, 2016) and theory of mind (Nguyen & McDermott, 2024). For instance, Nguyen and McDermott (2024) recently demonstrated a strong link between theory of mind and cross-categorization performance. This finding suggests that categories not only reflect objective structures but also how individuals, as categorizers, create them (see Malt, 1995, for discussion). This might be particularly relevant in the food domain, where even infants' reasoning about food is inherently social and flexible, allowing them to infer food choices based on social groups and relationships (Liberman et al., 2016; Shutts et al., 2009).

Conversely, our study also carries practical implications for food education programs. Previous research (e.g., Lafraire et al., 2020; Pickard et al., 2023; Rioux et al., 2018b) suggests that knowledge-based interventions (Gripshover & Markman, 2013; Nguyen et al., 2011) promoting children's understanding of food situations can increase dietary variety. Our interindividual difference approach of categorization and neophobia suggests that a *one-size-fits all* approach may not be equally effective for all children, particularly those with high level of food neophobia. While these programs aim to enhance children's conceptual knowledge about food, our data suggest that cognitive rigidity in neophobic children may prevent them from broadening their food repertoire and habits. This could explain why interventions are generally less effective for highly neophobic children (de Wild et al., 2017; Rioux et al., 2018b; Zeinstra et al., 2017).

Conclusion

In conclusion, the present study examined individual differences in categorization development. Performance improved with age, and these improvements in both categorization tasks were mediated by accumulated factual knowledge and also executive functions. While greater factual knowledge led to better performance, discriminating between vegetables and nonvegetables involved working memory and cognitive flexibility, whereas performance in cross-categorization was associated with better cognitive flexibility. Another important finding is that specific child-individual differences can undermine categorization development, either directly or indirectly. In our research, the adverse effect of food neophobia on categorization performance was not linked with accumulated factual knowledge. Instead, the poor performance observed in neophobic children was partly explained by lower cognitive flexibility. Interestingly, food neophobia also exerted a negative impact independently of any of the mediators considered in the present research. This important result emphasizes the role of individual differences related to how children develop specific conceptual knowledge. In that perspective, our case is an illustration of the complex interplay between child characteristics in shaping the development of categorization abilities.

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Received September 25, 2023
Revision received April 10, 2024
Accepted April 11, 2024 ■