JOURNAL OF COGNITION AND DEVELOPMENT
https://doi.org/10.1080/15248372.2025.2589107

To Be or Not to Be: The Effects of Transformations on Category Membership of Foods versus Non-Foods

Helana Girgis [a], Simone P. Nguyen [b], Jérémie Lafraire [c], Jean-Pierre Thibaut [d], and Camille Rioux [e]

[a]Stockton University; [b]University of North Carolina Wilmington; [c]Institut Paul Bocuse Research Center; [d]Université of Bourgogne France-Comte; [e]Université Paris Descartes

ABSTRACT

Categorization strategies differ based on an item's origins, for example, those that are natural versus human-made. However, it is unclear if and how foods fit into these categories since these can be both natural and human-made (processed), and both types of foods have a history of human intervention. Across two studies, 189 four- and five-year-olds ($M_{age} = 5.09$, > 50% White), six- and seven-year-olds ($M_{age} = 6.69$, > 50% White), and adults ($M_{age} = 19.34$, > 50% White) were recruited from a Northeast community in the United States. They viewed pictures or were told about natural and processed foods, natural kinds, and artifacts undergoing transformations, and were asked if the transformed item remained the same. Category membership judgments differed for foods and non-foods, and for older participants, between processed and natural foods. This suggests that food differs from non-food domains, which requires more than a single categorization strategy.

Categorization is an integral part of a human's ability to reason and a necessary part of building a cohesive, integrated mental representation of the world (Carey, 1985; Murphy, 2004; Owen & Barnes, 2021). Knowledge of origins, such as whether an item is natural or human-made, is a cue to prioritizing certain sets of properties that children rely on when identifying members of a category (Gopnik & Sobel, 2000; Meunier & Cordier, 2009). Inherent to natural kinds is that category members are created by nature, and, subsequently, are considered objective, discrete categories (e.g., animals, plants, minerals; see Rhodes & Gelman, 2009). Conversely, artifacts are made by humans with the purpose of meeting some human need (e.g., toys, furniture, automobiles) with flexible category membership dependent upon their intended or current function (see German & Johnson, 2002).

While young children use external properties to guide their category decisions for natural kinds, by four years old, they place greater emphasis on internal properties as a reliable indicator of category membership (Bailenson et al., 2002; Diesendruck, 2001; Gelman & Markman, 1986). Given that these category members are created by nature, the expectation is that internal properties are stable or similar throughout the item, often unobservable, and responsible for their being in that category (Opfer & Bulloch, 2007; Springer & Keil, 1991). In a seminal series of studies, Gelman and Markman (1986)

CONTACT Helana Girgis helana.girgis@stockton.edu Stockton University, 101 Vera King Farris Dr, Galloway, NJ 08201 USA
Supplemental data for this article can be accessed online at https://doi.org/10.1080/15248372.2025.2589107

presented four- to six-year-olds with target pictures of a bird (flamingo) and a bat and were told the different properties of each. Then, a test picture of an animal that looked like a bat but was labeled a bird was presented, and children were asked if it had properties like the target bird or bat. Children relied on the *label* rather than on perceptual features to categorize the test picture, saying the test picture was similar to the bird rather than the bat. Although bats can fly like birds, their category label emphasizes deeper biological traits (e.g., mammal) that go beyond mere surface similarities. Thus, category membership itself is indicated by the item's label, as it represents a rich set of conceptual properties, comprising the observable and unobservable (Gelman, 2023; Gervits et al., 2023; c.f. Sloutsky, 2018). Similar categorization strategies for natural kinds, beginning at the same age, have been observed across different cultures (Diesendruck, 2001; Waxman et al., 2007).

For human-made artifacts, young children will also use external properties, such as shape, to guide their category decisions; however, by age the age of four, children expect an item's intended or current function to be a more reliable indicator of category membership (Gopnik & Sobel, 2000; Kemler Nelson et al., 2000; Kimura et al., 2018). Evidence supports that four-year-olds, when presented with a perceptual match (e.g., two objects that look the same, but with different functions) versus a functional match (e.g., two objects that do not look the same, but with the same function), categorize based on the functional match (Casler & Kelemen, 2005; Kimura et al., 2018). Similarly, four-year-olds presented with a perceptual match (e.g., a key that looks like a spoon) versus the creator's category label for the item (e.g., it is a key) were more likely to rely on the creator's *label* rather than on perceptual features (Jaswal, 2006). Intention is also a salient factor for children when labeling an artifact. By around age four, children are more likely to label a novel object based on whether it was intentionally designed, even if its appearance or material is atypical, than if it came about by accident (Cimpian & Salomon, 2014; Gelman & Bloom, 2000).

While substantial bodies of research have investigated young children's category membership strategies for natural kinds and artifacts, this has yet to be established in the domain of food. Much of the research in the food domain has focused on children's knowledge of healthy and unhealthy foods, food selection and preferences, social judgments, and selective trust (for example, see DeJesus et al., 2019; Menendez et al., 2020; Nguyen, 2007; Nguyen et al., 2016), but less has been specific to categorization strategies (though see Foinant et al., 2022; Lafraire et al., 2020; Nguyen, 2020; Nguyen & Murphy, 2003). This is surprising, considering food is a complex domain with multiple layers, making it a critical area of research of its own. In part, the complexity stems from category members that can be both natural (e.g., broccoli) and human-made (processed, e.g., cheese). Natural foods are natural in the sense that they are dependent upon biological properties for growth, such as photosynthesis derived from the soil, air, and sun. In contrast, people make processed foods by combining ingredients and creating physical or chemical transformations (e.g., adding emulsifiers or additives). An additional level of complexity stems from a food's function, as it is intended for human consumption, and thus, even natural foods have a history of human intervention. For example, even though natural foods are not created by humans, they are often purposefully planted, harvested, stems cut and trimmed, packaged, and shipped to the grocery store. Thus, foods comprise basic-level category members that cut across the standard distinction in which origins (natural or human-made) are stable within a superordinate level category.

While our knowledge of how children's food concepts develop continues to grow, thus far, there is no unifying theoretical explanation. One goal of this research is to clarify potential theoretical explanations. One possible model for how children categorize natural and processed foods is that these foods are not grouped under a distinct, superordinate "food" category, but instead are extensions of broader existing ontological categories: natural foods are treated as a type of non-food natural kinds (hereon referred to as natural kinds) and processed foods as a type of artifact. In this model, children's judgments about category membership for natural foods follow the same principles they use for natural kinds, relying on internal, essential properties, while judgments for processed foods follow the reasoning applied to artifacts, relying on function and intentional design.

A second possibility is that children categorize items based on their intended function rather than internal or external properties (Kelemen, 1999). In this model, children judge whether an item remains the same kind following a transformation by considering whether its core function has been preserved: functional continuity predicts categorical continuity (Rose & Nichols, 2019). If this is the case, then a food's origins are not used to categorize it, only its function. Therefore, there would be no differences in how natural versus processed foods are categorized using one rule to categorize all foods, which is their function.

A third possible model is that children conceptualize food as its own distinct category, not reducible to either natural kinds or artifacts, and not categorized by function alone. Instead, it is treated as a hybrid or borderline case that draws features from both domains (Bloom, 2007; Malt, 1994). Rather than applying a single categorization strategy, foods lie on a continuum, and children consider origin (natural versus human-made), function (intended use), and level of human intervention/manipulation (e.g., level of processing) when making category judgments (Gelman, 1988; Girgis & Nguyen, 2020; Lafraire et al., 2020; Nguyen, 2020). In this case, categorization strategies for foods differ from non-foods (natural foods ≠ natural kinds, processed foods ≠ artifacts), and natural foods are not categorized the same as processed foods. The model predicts a flexible, integrative categorization strategy, where children use multiple dimensions when deciding a food's category.

A growing body of research has begun to examine these questions. Similar to natural kinds and artifacts, children use certain external properties to guide their category decisions. For example, three- to four-year-olds are more likely to use color, compared to shape, when deciding whether a novel item is a food (Marcario, 1991). Moreover, evidence supports that children believe that internal properties are a more reliable indicator of their category membership. Girgis and Nguyen (2018) found that when a food's appearance differs from its substance or insides (candy shaped to look like an apple), five- and six-year-olds use a food's substance to identify it. In terms of origins, three-year-olds classify natural foods as naturally occurring (grown in a garden) and processed foods as human-made (made in a factory), though accuracy improves with age (Girgis & Nguyen, 2020). However, children's knowledge of food origins is not as well developed as their knowledge of non-food origins, with better performance for the latter than the former at younger ages. Lafraire et al. (2020) provided further support, finding six- and seven-year-olds did not believe that an artifact's novel functional properties were present in pureed foods (human-made origins); similarly, they did not believe a natural kind's novel essential properties were present in whole natural foods (natural origins). While limited, this initial evidence suggests that children do not categorize natural and processed foods as natural kinds and artifacts, respectively.

Yet, children are also not using the same strategies to categorize natural and processed foods. While children were similarly accurate in identifying the origins of familiar and unfamiliar natural foods, they were significantly less accurate for unfamiliar processed foods as compared to familiar processed and natural foods, and unfamiliar natural foods (Girgis & Nguyen, 2020). Additionally, it appears that children consider the extent to which food is manipulated by humans (i.e., processed) as a cue for whether it is natural or processed. While young children (three- to five-year-olds) do not consistently use processing cues if the food is preserved in its whole form (e.g., frozen strawberries in a bag are made in a factory; Girgis & Nguyen, 2020), even three-year-olds used slicing as a cue in identifying a food from a non-food, and properties of edibility (Foinant et al., 2022).

Current research

The goal of this study was to further investigate children's categorization strategies of natural and processed foods, in comparison to natural kinds and artifacts. A range of well-established methods was used to test children's categorization strategies. Pertinent to the current research were those methods examining categorization strategies after an item is transformed by disrupting its internal, functional, and/or external properties. After the transformation, children were asked whether it still belonged to the same category or not (see Gutheil et al., 2004; Keil, 1992; Lafraire et al., 2020; Gelman & Wellman, 1991). In making this judgment, children were actively engaging in categorization, deciding whether the transformed item still fit within the conceptual boundaries of the original category. When children believe that the label stays the same despite a transformation, it indicates that they have determined the disrupted property is not essential for belonging to that category.

For natural kinds, disrupting internal properties is more likely to disrupt category membership. For example, four-year-olds believe dogs are no longer dogs when their insides, like blood and bones, have been removed (Gelman & Wellman, 1991), yet they believe dogs are still dogs if their external properties, such as appearance or proper name, change (Gutheil & Rosengren, 1996; Keil, 1992). For artifacts, disrupting functional properties is more likely to disrupt category membership, though there are developmental differences in category judgments. Young children use an artifact's current function, which conveys an ahistorical approach. By age six, children shift to using the intended function or object history, prioritizing the function it was intentionally created to fill (Chaigneau & Barsalou, 2008; Gutheil et al., 2004). For example, six- and seven-year-olds believe that an envelope cut into pieces is still an envelope since it was intentionally created to be one. Four- and five-year-olds, however, believe it is no longer an envelope since it cannot be used as such (Gutheil et al., 2004).

We aimed to extend Gutheil et al.'s (2004) and Wellman and Gelman's (1992) studies by examining four- and five-year-olds, six- and seven-year-olds, and adults' judgments of category membership for natural and processed foods in comparison to natural kinds and artifacts after a series of transformations. These age groups are typically tested in food research, and reflect the ages that children can identify the origins of natural and processed foods (four and five years) and emerging shifts in the reasoning processes (six and seven years; DeJesus et al., 2019; Foinant et al., 2021; Girgis & Nguyen, 2018, 2020; Hickling & Gelman, 1995; Lafraire et al., 2020).

In Study 1, participants viewed a series of pictures depicting natural and processed foods, natural kinds, and artifacts that underwent two transformations that disrupted their functional properties: cutting and crushing. For each item, a classification task was followed by a transformation task, which included pictures of the item, the transformation, and the transformed item. In Study 2, we expanded the types of items and transformations, which now disrupted functional and internal properties: removing insides, crushing, and melting. Due to the number of stimuli and types of transformations, pictures were not used. For both studies, after each transformation, participants were asked whether the transformed item was "an X or not an X." Test questions used the specific label of the item, though, for example, "Is this an apple or not an apple?" If participants replied that it was X (e.g., apple), then the transformation did not change its category membership, and if participants replied that it was not an X (e.g., not an apple), then the transformation did change its category membership. This method is consistent with research on category-based induction, which shows that children and adults use labels as cues to category membership and infer shared properties based on shared labels (for example, see Gelman & Markman, 1986; Gelman, 2003; Gutheil et al., 2004; Kalish, 1998). Label use in these paradigms is a proxy for category-based reasoning: if two items share a label, they are assumed to belong to the same category and possess the same properties.

Transformation tasks offer a novel approach to this question by revealing which properties children deem essential for category membership, specifically, what must remain unchanged for an item to continue to be classified within a given category. Furthermore, transformation tasks offer a method to assess the strength and flexibility of children's category boundaries, providing insight into the conceptual framework that underlies these categorization judgments. Transformations are also a salient and frequent feature of food. Unlike natural kinds or artifacts, food is routinely altered—sliced, chopped, combined, or cooked—often on a daily basis. These real-world experiences may make food transformations particularly meaningful to children, influencing how they interpret changes in food items compared to other domains.

This research contributes to both theoretical understanding and practical applications concerning children's developing concepts of food. Theoretically, a critical part of cognitive development is gaining insight into how children think across different areas, which can uncover general cognitive principles. Even though food is a specific area, it is directly connected to children's developing knowledge structures, providing insight into how they integrate knowledge from broader domains, such as natural kinds and human-made artifacts. Practically, properties that children consider central to a food's identity can inform age-appropriate approaches to health and nutrition education aimed at promoting informed food choices and helping children distinguish between foods and non-foods. It also includes identifying possible processes behind disordered eating practices and reducing accidental poisonings.

Based on previous literature, we expect that categorization responses will support the hybrid model. In this model, categorization is not based solely on origins or function, but rather on a combination of both, with variations depending on the extent of human intervention. While some of this is exploratory, we predict:

- Based on the included types of transformations, participants will be more likely to judge foods as part of the same category compared to non-foods.

- Judgments will differ between processed and natural foods. Since natural foods possess biologically based internal properties, certain transformations, such as removing the insides, may be more likely to change their category membership than processed foods.
- Older age groups tend to consider the intended function of items more than their current state. Therefore, we expect them to judge items as having the same category membership after a transformation more than younger age groups.

Study 1

Method

Participants

Participants included thirty-one four- and five-year-olds (M_{age} = 5.16, *range* = 4.00–5.91, 12 females), thirty-five six- and seven-year-olds (M_{age} = 6.81, *range* = 6.05–7.82, 18 females), and 31 adults (M_{age} = 19.00 years, *range* = 18.00–21.00 years, 24 females). Three four- and five-year-olds were excluded due to their inability to complete the study (e.g., did not respond to questions). Sample size was based on previous studies on the development of reasoning about food origins and object transformations, which yielded similar effect sizes (e.g., Girgis & Nguyen, 2020; Gutheil et al., 2004). Participants were recruited from preschools, elementary schools, and one university located in a predominantly lower-middle-class township in the Northeastern United States. Participant race and ethnicity were not individually recorded. However, according to demographic data provided by the superintendents' offices for the respective schools, the student populations were predominantly White. This is also supported by the community's demographics, which is majority White (86.1%; 78.0%, respectively; U.S. Census Bureau, 2023a). The study was approved by the university IRB, and informed consent was obtained from adults and parents/guardians of child participants. Assent was obtained from child participants.

Materials

Stimuli included a total of eight items: two natural foods (apple, broccoli), two processed foods (bread, chocolate), two natural kinds (branch, cactus), and two artifacts (ball, pencil). Foods were selected to represent two types of natural (fruits and vegetables) and processed foods (savory and sweet), while artifacts were selected to be hollow (ball) and not hollow (pencil). These specific items were informed by previous related research that used these common items (Gutheil et al., 2004; Wellman & Gelman, 1992). Pictures were taken of each of the target items (item before the transformation), which were purchased or found. Pictures for the classification task were colored photographs found from online search engines (e.g., Bing Images) or used in previous research (Girgis & Nguyen, 2020). Using online editing tools, photographs were standardized with a single image of the item on a white background.

The classification task included two target category pictures: one of the target item (e.g., apple) and one of the target item with a gray "X" over it (e.g., apple with an "X" over it). The classification task included four pictures per target item, which were the following: identical to the target picture (e.g., apple), a different item from the same target category (e.g., a picture of a different apple), and two not from the target category but from the same superordinate category (e.g., strawberry and lemon). See Supplemental Information (SI) 1.1 for a list of the foods used that did not belong to the target category.

For the transformation task, the transformations were "cut" and "crush." Each transformation included three pictures. For both transformations, the first picture was the same as the target category picture. For the cut transformation, the second picture showed a female adult (a research assistant who was not part of the data collection) holding a 10-inch chef's knife against the item. For the crush transformation, the second picture showed the same adult holding a hammer against the item. For these pictures, the adult was looking down at either the knife or the hammer. The items were on a table covered with a white tablecloth, and the images were edited to ensure uniform brightness. The third picture was the cut or crushed item. For the cut transformation, using editing tools in Microsoft Word, items were split into three parts, with each part laid out side by side in a horizontal line, not touching each other. For the crush transformation, the item was crushed in the lab with a hammer and arranged in a horizontal line. A picture was taken and then edited to display only the image on a white background. See Appendix A for sample pictures of target categories.

Procedure

The procedure was the same for both adult and child participants, except for the testing location. All participants were tested individually for approximately 15 minutes by a researcher. Children were tested either at their school or in an on-campus laboratory, whereas adults were tested in an on-campus laboratory.

Researchers introduced the study by telling participants they would be asked to figure out what some things were. There were eight items, or trials, and two tasks per item that were presented in sequence: the classification task followed by the transformation task. For the classification task, the researcher labeled the item in the target category picture, then asked participants to classify four pictures as either the target item or not, shuffling the four pictures prior to each trial. No participants incorrectly classified the pictures more than once. This activated the item's category and ensured that participants understood it well enough to identify pictures that were similar but not identical (e.g., red apple target picture, green apple test picture).

The transformation task followed immediately after the classification task. Pictures were presented one at a time for both transformations. Holding the first picture of the item in front of the participant, the researcher labeled it and its origins. For human-made items, researchers said they could find them in a factory, which is where people go when they want to make things. For natural items, researchers said they could find them in a garden, and these things grow naturally in the ground. Then, researchers revealed the second picture of the transformation (e.g., hammer on the apple) and described the transformation (e.g., "Look what happens here. This person is crushing it"). The third picture was then presented, but was only labeled by how it was transformed (e.g., "Now it is crushed") and not by its name. While the researcher still held up the third picture, participants were asked whether it was X or not X (e.g., "Is this an apple or not an apple?"). In this apple example, if a participant identifies the transformed item as an apple, it means that they believe it belongs to the same category ("apple") as it did before the transformation. See Appendix A for the sample protocol.

Participants were shown the items in one of two random orders. For each trial, the presentation of the category target pictures, the order of the transformations (cut or crush), and the order of the response choices (category, not category) were counterbalanced.

The English version of the Child Food Rejection Scale (CFRS) was provided to parents with the consent form (CFRS, Rioux et al., 2017a, 2019). The CFRS includes two subscales corresponding to two dimensions of food rejection: food neophobia (six items) and pickiness (five items). On a 5-point Likert scale from 1 (*Strongly disagree)* to 5 (*Strongly agree*), caregivers were asked to what extent they agreed 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"). This questionnaire was administered because food rejection disposition seems to influence food categorization in preschoolers (Foinant et al., 2022; Pickard et al., 2021, 2023; Rioux et al., 2016, 2017b).

Scoring and statistical analysis

We assigned a score of 1 for *same-item* responses (e.g., is an apple), and a score of 0 for *different-item* responses (e.g., is not an apple) for each transformation. To test our main hypotheses, we used a linear mixed-effects model using a *binomial* distribution to analyze the probability of giving *same-item* responses ranging from 0 to 1 (Bates et al., 2015). Participants served as a random factor to account for shared variances within subjects. Item type (processed foods, natural foods, natural kinds, artifacts), age (adults, six- and seven-year-olds, four- and five-year-olds), and transformation (cut, crush), as well as their interactions, were modeled as fixed factors. Finally, using Spearman's correlation, we investigated whether children's individual scores of food rejection (assessed with the CFRS) were associated with different patterns of responses to the task.

The analyses were performed with R (R version 3.6.3; R Core-Team, 2021) running on RStudio version 0.99.896 (RStudio, 2016). Data and scripts used for statistical analysis are available on the Open Science Framework (OSF): https://osf.io/uednb/?view_only=843e556151bf440abe702e2481da7921

Results

See SI 2.1 for percent of same-item responses for each item, 2.2 for description of main effects, and 2.3 for description of interactions.

The best fit model was selected according to Akaike's Information Criterion and was the model including the main effects of item type, age, and transformation and two two-way interactions ($\chi2$ (14) = 426.67, $p < .0001$, marginal $R^2 = 0.35$, conditional $R^2 = 0.83$). Follow-up analyses on the main effect of item type (χ^2 (3) = 97.31, $p < .0001$) revealed more same-item responses for natural and processed foods compared to natural kinds and artifacts, and for natural kinds compared to artifacts (*ps* $\leq$.029). For the main effect of age (χ^2 (2) = 15.41, $p = .00045$), follow-up analyses revealed that adults provided more same-item responses than both younger age groups, and six- and seven-year-olds did more so than four- and five-year-olds (*ps* $\leq$ .033). For the main effect of transformation (χ^2 (1) = 120.62, $p < .0001$), follow-up analyses revealed more same-item responses for cut items than crushed, $p < .0001$.

These were qualified by two two-way interactions. The first was an item type and age (χ^2 (6) = 45.26, $p < .0001$) interaction (see Figure 1 Panel A). Adults gave significantly more *same-item* responses for both processed and natural foods than for natural kinds, all of which were above chance (binomial *ps* < .0001). They also gave more *same-item* responses for natural kinds compared to artifacts, for which they were at chance (binomial p = .088).

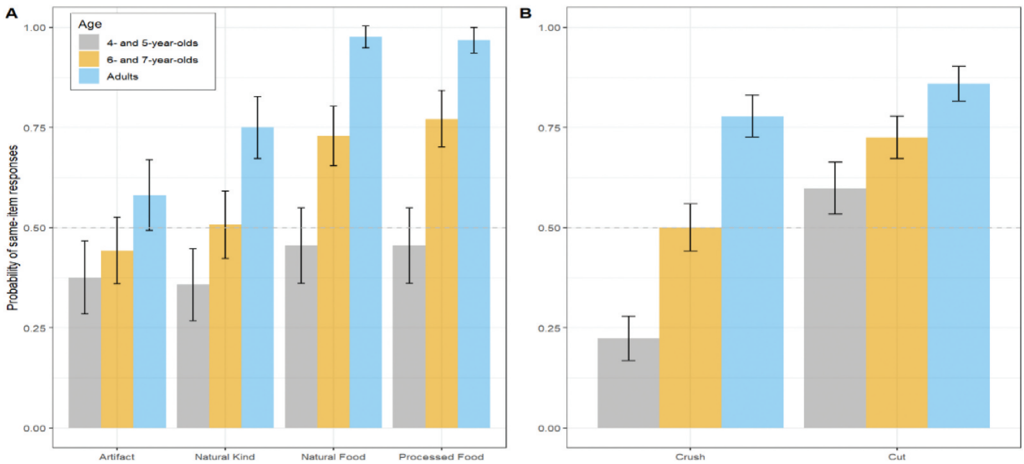


Figure 1. Probability of same-item responses in Study 1.

Six- and seven-year-olds gave significantly more and above chance (binomial *ps* < .0001) *same-item* responses for both types of food, compared to natural kinds and artifacts, for which they were at chance (binomial *ps* > .2). Finally, four- and five-year-olds did not change their pattern of responding across the four item types but were at chance responding for both food types (as attested with binomial tests, *ps* > .3), while below chance for natural kinds (p = .0032) and artifacts (p = .010). Regarding age differences, for both processed and natural foods, adults and six- and seven-year-olds gave more *same-item* responses than four- and five-year-olds. For natural kinds, four- and five-year-olds only differed from adults. No age differences were found for the artifact items.

The second interaction was transformation and age (χ^2 (2) = 16.45, p = .00027; see Figure 1 Panel B). In all age groups, participants gave more *same-item* responses for the cut transformation. For the cut transformation, only four- and five-years-olds significantly differed from adults, though all age groups were above chance (binomial *ps* < .004). For the crush transformation, all age groups responded differently: adults were above chance (binomial $p < 0.0001$), six- and seven-year-olds were at chance (binomial $p > .05$), and four- and five-years-olds were below chance (binomial $p < .0001$).

Examining children's individual level of food rejection changed the pattern of responses; CFRS scores ranged from 24 to 55 ($M = 37.56$, $SD = 6.26$), with a higher score indicating more food rejection behaviors. The distribution was similar to previous studies using the English version of the CFRS (Rioux et al., 2019). We found that the more neophobic and pickier the children were, the more they gave *same-item* responses during the task, though the effect size was small (Spearman $r = .16$, $p < .0001$).

Discussion

As in previous research, older age groups provided more category membership responses than younger ones, and adults judged natural kinds as retaining their membership more so than artifacts. While both younger age groups did not differentiate in their responses for the non-food categories, only four- and five-year-olds judged them as not the same thing after the transformations, whereas six- and seven-year-olds were at chance. Similar to findings in previous literature (for example, see Gutheil et al., 2004), it could be that with more experience, people are likely to use multiple properties (e.g., object history) when determining category membership, unlike younger children who may more narrowly apply select properties (e.g., only considering current state). While these transformations were meant to disrupt functional properties, children's lack of differentiation between natural kinds and artifacts suggests they believed those transformations significantly disrupted the membership of both, with a possible transition emerging at six and seven years of age. It may indicate distinctions between natural kinds and artifacts are still developing for four- and five-year-olds, at least for these transformations and stimuli.

In addition, there were fewer same-category membership judgments for crushed items than for cut, though this varied by age, with younger participants more likely to consider items as not the same after being crushed. This is similar to previous research, as crushing more thoroughly degrades the item compared to cutting. It also suggests that younger children are more likely to consider category membership based on its current form than older age groups. While from a food science perspective, crushing does not change one possible purpose of foods—their edibility. For instance, the food could have looked unpalatable, and they decided they would not eat it. This is supported by the few spontaneous comments from children in the youngest age group (e.g., "ewww, that's gross," "it's all smushy and yucky"). An alternative explanation, though, is that hammers are not typically used on foods, and children based their decision on the person's intention to create something different with the hammer.

For foods, adults judged natural and processed foods as retaining their category membership after both transformations more so than non-foods (natural and processed foods > natural kinds > artifacts), as did six- and seven-year-olds (natural and processed foods > natural kinds and artifacts). Four- and five-year-olds did not differ in their category membership judgments among any of the items. These results support that older children and adults are not treating natural foods as a natural kind and processed foods as an artifact, but as their own separate domain. Moreover, given the similar category membership judgments for both food types, it appears that adults and children are not considering food origins but treating foods as a single, uniform domain. However, an alternative explanation could be that these transformations did not change a food's functional or internal properties. In terms of developmental differences, six- and seven-year-olds considered both types of food to be the same after the transformations, while four- and five-year-olds were at chance. It may be that the reorganization of categorization strategies for foods emerges at a younger age than for non-foods.

Finally, the more neophobic and pickier the children were, the more likely they were to judge category membership as staying the same after the transformations. This adds to the existing literature, which has found that neophobic children are less likely to interact with food, discriminate between foods, and correctly categorize foods compared to children who are less neophobic (Lafraire, Rioux, Giboreau, et al., 2016a; 2016b; Rioux et al., 2016, 2017b, 2018).

Study 2

The main goal of the second study was to include a transformation that disrupted a food's internal properties. Therefore, expanding on Wellman and Gelman (1992), we added a "removing-insides" transformation. In addition, a melting transformation was included to disrupt the internal properties of natural kinds and the current functional properties of an artifact. To examine whether the pictures of the crushed items influenced category membership responses, we included "crushing" as the third transformation. Finally, we increased the number of items and intentionally included ones that varied in makeup and content. Considering the types of transformations and stimuli, verbal descriptions were used instead of pictures.

Method

Participants

Participants included twenty-eight four- and five-year-olds (M_{age} = 4.98 years, *range* = 3.9-–5.98, 15 females), thirty-five six- and seven-year-olds (M_{age} = 6.58 years, *range* = 6.00–7.49, 19 females), and 29 adults (M_{age} = 19.68 years, *range* = 18.32–21.96, 17 females, 1 non-binary). Data collection occurred at preschools, elementary schools, and one university located in a predominantly middle-class township in the Northeastern United States. Participant race and ethnicity were not individually recorded. However, according to demographic data provided by the superintendents' offices for the respective schools and for the university, the student populations were predominantly White. This is also supported by the community demographics in the middle-class township, where adults are a majority White (61%), and child ethnicity was reflective of the school district, with 44% White, 22% Black or African American, 19.8% Hispanic/Latinx, and 11.2% Asian (U.S. Census Bureau, 2023b). The study was approved by the university IRB, and informed consent was obtained from adults and parents/guardians of child participants. Assent was obtained from child participants. No participants from Study 1 participated in Study 2.

Materials

Stimuli were expanded to include meats and dairy for foods, animals for natural kinds, and items with mechanical insides for artifacts. Meat was included for natural (shrimp) and processed foods (chicken nuggets) to expand beyond plant-based foods. Eggs and cheese were included as foods from animals rather than only from plants or mechanically produced. Specifically, eggs and shrimp were included, as they are both naturally occurring and typically have an outer covering that is removed to be consumed (though all parts of these foods are edible). The types of natural kinds were also expanded to include animals (flies and worms) to compare with non-food plants. Lastly, artifacts that had mechanical insides (clocks and cars) were included to compare with those without mechanical insides.

Stimuli were a total of 16 foods and non-food items: four natural foods (apple, broccoli, egg, shrimp), four processed foods (bread, chocolate, cheese, chicken nugget), four natural kinds (branch, cactus, fly, worm), and four artifacts (ball, pencil, car, clock). These stimuli underwent three transformations: removing the insides of the item, crushing the item with a hammer, and adding a lot of heat to melt the item.

Procedure

Children were tested individually for approximately 20 minutes by a researcher at their school or in an on-campus laboratory. The procedures for the child and adult participants were identical, with the exception that adults were told that this research was for a developmental lab and were tested in an on-campus laboratory.

To begin, the researcher explained that participants would hear stories about some things the researcher's friends were doing. To ensure that participants did not think the three transformations were performed on the same item, the researcher stated that their friend had three of the same items and identified their origins. The participants were then told this friend did one of the following transformations on one of the items: removing the insides, crushing with a hammer, and putting a lot of heat to melt the item. Participants were asked after each transformation if the item was an X or not an X (e.g., "The first thing my friend did was to take all the insides out of the first apple. After the insides were taken out, is it an apple or not an apple?"). To ensure there was no confusion about less familiar items, the researcher defined the terms cactus, shrimp, and melt for child participants. The cactus was defined as a plant that grows in the desert and has spiky thorns on it; shrimp as a food that comes from the ocean; and melting as when something gets really hot and then melts, getting ooey gooey like ice cream when it gets hot and soft. As in Study 1, if a participant identifies the transformed item as an apple, it means that they believe it belongs to the same category ("apple") as it did before the transformation. Explanations were asked for a subset of items from each category: ball and clock, branch and fly, chicken nugget and chocolate, and broccoli and egg. These items were selected to represent the variety in each category.

Participants were shown the items in one of two random orders. The researcher randomly presented the transformation questions for each item, and the order of the test question choices was counterbalanced.

As in Study 1, prior to the testing session, parents filled out the CFRS (Rioux et al., 2017a).

Scoring and statistical analysis

Scoring procedure and statistical analyses were identical to Study 1. To examine the effect of modality on category judgments, an independent *t*-test was conducted on responses to the crush transformation for stimuli that were the same for Studies 1 and 2 (apple, broccoli, chocolate, bread, pencil, ball, branch, and cactus) by age group. To analyze explanations, we used a generalized linear mixed model with a Poisson distribution, modeling the frequency of explanations to test for main effects of age, item type, and transformation, as well as two-way interactions of each variable by explanation type (Age * Explanation Type, Item Type * Explanation Type, Transformation * Explanation Type).

Results

See SI 2.4 for the percent of same-item responses for each item, 2.5 for a description of main effects, and 2.6 for a description of interactions.

For the analysis of the probability of giving *same-item* responses, the best fit model was selected according to Akaike's information criterion and was the model including the main effects of Item type, age, and transformation and all the two-way interactions ($\chi2$ (23) = 555.33, $p < .0001$, marginal $R_2 = 0.23$, conditional $R_2 = 0.53$).

The results showed a significant main effect of item type (χ^2 (3) = 232,49, $p < .0001$), age (χ^2 (2) = 24.96, $p < .0001$), and transformation (χ^2 (2) = 103.40, $p < .0001$). Follow-up analyses for item revealed more same-item responses for processed foods compared to all other items, for natural foods compared to both non-food items, and for natural kinds compared to artifacts, *ps* ≤ .0004. For age, follow-up analyses revealed adults provided more same-item responses than both younger age groups (*ps* ≤ .002), but no difference between the younger two age groups. Follow-up analyses for transformation revealed more same-item responses for crushed items compared to items without insides or melted items, and more for items without insides compared to melted items, *ps* < .0001.

These main effects were qualified by three two-way interactions. As in Study 1, there was a significant interaction between item type and age (χ^2 (6) = 35.32, *p* < .0001 (see Figure 2). Adults gave significantly more *same-item* responses for processed foods than natural foods, natural kinds, and artifacts. They were below chance responding for artifact (binomial *p* = .0044), while above chance for the three other item types (binomial *ps* < .0003). Six- and seven-year-olds gave significantly more *same-item* responses for processed foods compared to the three other item types, and for natural foods compared to artifacts. They were at chance responding for processed foods (binomial *p* = .071), while below chance for the three other object types (binomial *ps* < .0001). Contrary to Study 1, though, four- and five-year-olds responded differently across the four item types: they gave less, and below chance, *same-item* responses for both natural kinds and artifacts (binomial tests, *ps* < .0001), compared to both types of foods for which they were at chance (binomial tests, *ps* > .7). Regarding age differences, for both processed foods and natural kind, adults gave more *same-item* responses than children did. For natural foods and artifacts, adults only differed from six- and seven-year-olds.

As in Study 1, there was a significant transformation and age interaction (χ^2 (4) = 77.50, *p* < .0001 *see Figure 2). Adults gave more *same-item* responses for crushed items (above chance, binomial *ps* < .0001) than items without insides (above chance, binomial *ps* < .0001), and melted items (below chance, binomial *ps* = .023). Six- and seven-year-olds gave more *same-item* responses for crushed items and items without insides compared to melted items (all below chance, binomial *ps* < .0001). Four- and five-year-olds did not change their pattern of responding across the three transformations (all below chance, binomial *ps* < .01). For crushed items and items without insides, adults gave more *same-item* responses than children, while for melted items, adults only differed from six- and seven-year-olds.

Unlike Study 1, these results revealed a significant interaction between transformation and item type (χ^2 (6) = 38.06, *p* < .0001 (see Figure 2). Regarding the crush transformation, participants gave more *same-item* responses for processed foods than natural foods (both above chance, binomial *ps* < .0001), natural kinds (at chance, binomial *p* = .76), and artifacts (below chance, binomial *p* = .00016). Regarding the insides-out transformation, participants gave more *same-item* responses for processed foods (which were at chance, binomial *ps* = .41) compared to natural kinds and artifacts (which were below chance, binomial *ps* < .0001). Regarding the melt transformation, participants gave more *same-item* responses for both types of foods (at chance, binomial *ps* > .12) compared to artifacts and natural kinds alike (below chance, binomial *ps* < .0001). Within item type, for both processed and natural foods, participants gave more *same-item* responses for crushed items compared to the two other transformations. For natural kinds and artifacts, participants gave more *same-item* responses for both the insides-out and crush transformation compared to the melt transformation.

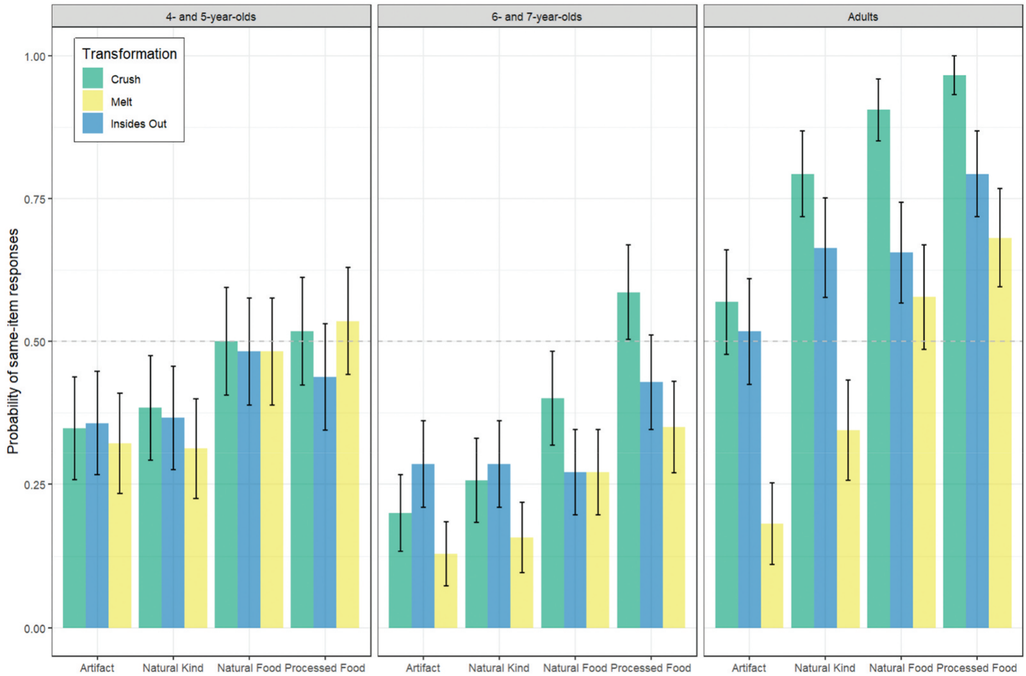


Figure 2. Probability of same-item responses in Study 2.

To further explore any potential differences in same-item responses between processed and natural foods by transformation, three paired sample *t*-tests were conducted for each age group separately. These were Bonferroni corrected with a *p*-value of .016 (.05/3). The analyses revealed that adults and six- and seven-year-olds provided more same-item responses for processed foods after their insides were removed ($M = 79.3\%$, $M = 42.8\%$, respectively) compared to natural foods ($M = 65.5$, $M = 27.1\%$), $t(28) = 2.73$, $p = .005$, $t(34) = 2.89$, $p = .003$, and for processed foods after being crushed ($M = 96.5\%$, $M = 58.5\%$, respectively) compared to natural foods ($M = 90.5\%$, $M = 40.0\%$,), $t(28) = 2.25$, $p = .016$, $t(34) = 3.23$, $p = .001$.

The results of the study comparison revealed four- and five-year-olds gave significantly more same-category membership responses in Study 2 compared to Study 1 for crushed artifacts, $t(53) = 2.05$, $p = .045$; $d = .38$, crushed natural kinds, $t(53) = 2.05$, $p = .045$; $d = .38$, natural foods, $t(53) = 2.73$, $p = .008$; $d = .38$, and processed foods, $t(53) = 2.32$, $p = .024$; $d = .40$. Adults gave significantly more same-category membership responses for processed foods in Study 2 than in Study 1, $t(58) = 2.03$, $p = .046$, $d = .12$ There were no other differences in same-category membership responses between the studies for six- and seven-year-olds and adults, $ps \geq .098$.

Contrary to Study 1, children's individual level of food rejection did not change the pattern of responses. The children's scores on the CFRS ranged from 22 to 55 ($M = 36.56$, $SD = 8.23$), and the distribution was similar to previous studies using the English version of the CFRS (Rioux et al., 2019), but we did not find any correlation between children neophobic status and their answers to the task (Spearman $r = .002$, $p = .92$).

Explanations

Responses to the explanations were coded if it referred to the following: 1) function, including edibility, 2) internal properties, 3) transformation only, 4) basic or superordinate category membership, 5) physical or external properties, e.g., appearance before or after the transformation, and 6) miscellaneous. The code was created to be detailed enough to differentiate between explanations that provided a deeper understanding of the change to an item's category membership from those that did not. For example, internal properties (e.g., "not chemically changing the item") explanation provided a deeper level of insight into the effect of the transformation compared to those explanations referring to a basic or superordinate category membership (e.g., "because it is still bread"). Multiple codes were used for explanations that referred to more than one type of explanation. See SI 2.3 for means of explanation type by age.

Two research assistants from the first and last authors' different labs independently coded a total of 2,208 explanations (92 participants each with 24 explanations). Follow-up discussions occurred for explanations about "death" for the fly (e.g., "it's just dead"). Both parties came to the agreement that death referred to internal, nonobvious properties rather than physical characteristics. Using Cohen's Kappa, interrater reliability was measured for each item, which revealed substantial agreement across all items, $\kappa \geq 71.70$, *ps* < .001.

In the analysis of the explanation frequencies, the best fit model was selected according to Akaike's information criterion and was the model including the main effects of explanation, age, item type, and transformation, and the two-way interactions between explanation ($\chi 2$ (35) = 763.25, $p < .0001$, marginal $R_2 = 0.84$, conditional $R_2 = 0.87$).

The results showed a significant main effect of explanation (χ^2 (5) = 254.03, $p < .0001$) and age (χ^2 (2) = 30.52, $p < .0001$), and three two-way interactions. The first is an age and explanation type (χ^2 (10) = 396.15, $p < .0001$), with the following significant differences: four- and five-year-olds provided fewer explanations referring to function, internal and external properties, and transformations only, and more miscellaneous explanations than the older age groups, while six-and seven-year-olds provided more function, transformation only, and miscellaneous explanations than adults. The second is a transformation and explanation (χ^2 (10) = 151.50, $p < .0001$), with the following significant differences: for the crush transformation, more explanations referred to external properties than any other; for the insides-out transformation, fewer explanations referred to transformation only and category membership than any other, and more external property explanations than function; for the melt transformation, more explanations referred to external properties than any other and fewer for internal properties than all others except for category membership. In addition, there were more explanations referring to internal properties for the insides-out transformation than the crush and melt transformations. The third is an item and explanation (χ^2 (15) = 108.81, $p < .0001$), with the following significant differences: artifacts had more explanations referring to function than any other item, while natural kinds had the least function explanations compared to all other items (foods did not differ), and there were more external property explanations for natural and processed foods and natural kinds as compared to all other explanation types.

To explore whether edibility was guiding participants' categorization strategies for food, explanations for foods that referred to edibility (e.g., "outsides can't be eaten," "can still eat it even if it's liquidy") were calculated. Adults (M = 19.0%) and six- and seven-year-olds (M

= 18.5%) provided more edibility explanations compared to four- and five-year-olds (M = 4.5%), $F(1, 92) = 4.86$, $p = .01$. See Table 1 for sample explanations by age.

Discussion

Similar to Study 1, adults gave more same-category membership responses than both younger age groups, though contrary to Study 1, six- and seven-year-olds' responses did not differ from four- and five-year-olds'. As predicted, there were fewer same-category membership responses for natural kinds and artifacts, indicating that these transformations did disrupt internal and functional properties, respectively. Explanations also supported that participants thought removing the insides transformation disrupted internal properties, as this was referred to more often than for crush or melt transformations. Once more replicating the response pattern in Study 1, adults gave more same-category membership responses for natural kinds compared to artifacts, while younger age groups did not differentiate between them. This may, in part, be explained by adults' higher number of category membership responses after the crush transformation, as it was meant to disrupt functional properties only, while the other two transformations were meant to disrupt internal and functional properties. Adults' explanations also support an overall higher threshold for a category member to cease being part of that category, and prioritizing labels and intended function (e.g., "it's just a dissected fly," "still a fly but it's dead," "inside out doesn't change a fly [ex; take organs out of a human]"). In contrast to Study 1, six- and seven-year-olds believed natural kinds and artifacts were not the same after the transformations (below chance). From this, it appears that six- and seven-year-olds may not be in a state of transition but rather are using the current status of these items to identify their category membership.

Examining responses for foods, all age groups gave more same-category membership responses for foods as compared to non-foods; however, only six- and seven-year-olds and adults differentiated between processed and natural foods. Adults judged processed foods stayed the same after the transformations the most, followed by natural foods, natural kinds, and artifacts (processed foods > natural foods > natural kinds > artifacts). Six- and seven-year-olds judged processed foods stayed the same after transformations more so than all other items, and natural foods stayed the same more than artifacts, but not natural kinds (processed foods > natural foods (= natural kinds) > artifacts = natural kinds). Even with these differences, they did judge all items as not part of the same category after the transformation, except for processed foods, which were at chance. Compared to Study 1, expanding the types of items and transformations revealed differences in four- and five-year -olds' judgments, with more same-category membership responses for both food types compared to non-foods (processed and natural foods > natural kinds and artifacts). However, similar to Study 1, they continued to judge non-foods as not the same after the transformation, though they were at chance for foods. Additionally, crushing and removing the insides was less likely to disrupt the category membership of processed foods compared to natural foods for six- and seven-year-olds and adults.

The crushed transformation was included to examine whether category membership judgments differed for visual versus verbal cues. It did for four- and five-year-olds, who had more same-item category membership responses for verbal explanations (Study 2) compared to visual (Study 1), but there were no differences for the six- and seven-year-olds. In

Table 1. Sample explanations.

Explanation	Four and five years	Six and seven years	Adults
Function, including edibility	Because it still tastes the same Because you can still dip it in the ketchup Because it doesn't fly, a fly's gotta fly Because tools need it to go tick tock	Because all the stuffing go away and cannot taste anything Because it can't dance or fly Goes stringy, people can't use it, no throw it	Crushed up into little pieces, still edible Can still eat it (even in liquid) Same function as solid chocolate Can't use it as a ball but still a ball
Internal properties/ essence	Because melting down and can see the yolk Because it is still made out of a rooster Because it's dead, blood is gone Nothing it in it but air	Because crush so insides still an egg with broken parts Because all of the broccoli is inside it Because blood inside and can't live without blood in the body	Because the actual bread hasn't changed, same ingredients Once wood is out of it, not really a branch anymore Chemical change occurred
Transformation only	It's crushed Because it melted it Because it's insides are out	Because it is crushed with a hammer Because it melting Because insides out	Just crushed Just melted
Basic or superordinate category membership	It's flattened bread, can't change Looks like but isn't chocolate What's inside a branch? Because it can't be a branch, it won't ever be a branch again	Because nothing will happen, dirty hammer, dirty bread Eggs have shells, take egg out then only shell, and that's not an egg Because melt it, it's not a branch, not hard	It's melted broccoli Still same thing, just broken Still basically a fly just in different parts Turned crispy but still a fly
Physical or external properties	Because it has the same color as outside Because it still has leaves on it and brown stuff Because melted into flat and into a puddle	Because it'll be crushed but different, sticky with white stuff coming right out it Because it's a branch puddle Because it's not shaped like one	Didn't change the form of bread, still solid All the pieces are still there, it's just crushed Just deflated, shape can come back
Miscellaneous	I don't know Because I know it is Because really messy hands	Because I know it is Gross because gross Because you should cut it up so a mouse can eat it on the porch	Don't know Was natural

Study 2, the absence of visual cues may have reduced this perceptual bias in younger children, resulting in more consistent response patterns across age groups. Given that age-related differences in Study 1 were only apparent for processed and natural foods, these findings suggest that the presence of pictures influenced younger children's category judgments for foods. At the same time, the consistent pattern of responses in the older group across both studies provides additional support that six- and seven-year-olds were less affected by surface-level features and focused on deeper, conceptual criteria for category membership, supporting a developmental shift.

Lastly, there was no correlation between neophobic children and category membership judgments. This was unexpected, given that neophobic children were more likely to judge items as the same after a transformation in Study 1, and is also not supported by previous research (Lafraire, Rioux, Giboreau, et al., 2016a; 2016b; Rioux et al., 2016). It may be that pictures were a better cue for neophobic children in determining whether it is the same thing or not, especially given the previous studies examining neophobia used pictures rather than verbal descriptions (for example, Foinant et al., 2021; Lafraire, Rioux, Giboreau, et al., 2016a; 2016b; Pickard et al., 2021; Rioux et al., 2016, 2018).

General discussion

The central question was whether natural and processed foods are conceptualized using preexisting ontological categories based on origin (natural kinds/artifacts), or whether food might constitute a distinct domain of conceptual knowledge. Across two studies, children and adults in the United States were asked whether category membership stays the same after different types of transformations for a variety of natural and processed foods, natural kinds, and artifacts. Results indicate that children's and adults' categorization strategies for foods are not the same ones they use for non-foods, and older age groups differentially apply categorization strategies based on the origins of foods. Thus, the categorization strategies for natural foods differ from those for natural kinds, and processed foods differ from artifacts. Additionally, the categorization strategies for natural and processed foods are not the same. Taken together, foods may represent a conceptually distinct domain, providing support for a hybrid conceptual model. These results provide a strong foundation for future research in determining which properties are central to the functional and/or causal existence of natural and processed foods.

Both studies revealed that participants were more likely to judge foods, compared to non-foods, as retaining their category membership after transformations. Study 1, using pictures and functional disruptions (cutting and crushing), found that older children and adults judged foods as part of the same category more so than non-foods, unlike four- and five-year-olds, who did not differentiate category membership judgments between foods and non-foods. Study 2 expanded these findings by including a wider range of foods and non-foods, internal-property transformations, and removing visual cues. Here, older children and adults treated processed foods as more stable than natural foods, suggesting that the internal structure of natural foods was weighted more heavily in category membership decisions. Notably, crushing and removing insides disrupted the perceived identity of natural foods more than processed ones. While four- and five-year-olds did not judge category membership differently for processed and natural foods, they did differentiate between foods and non-foods.

These results support a hybrid conceptual model of food, in which categorization strategies draw upon, but are not reducible to, strategies used for natural kinds and artifacts. Yet, an argument might be made for the functional model since we did not explicitly test edibility, which is one core function of food. Yet, if edibility alone guided category membership for foods, it would not account for six- and seven-year-olds' and adults' different category membership responses to processed versus natural foods. For example, we found six- and seven-year-olds provided more category membership responses for crushed processed compared to crushed natural foods, yet crushing does not necessarily disrupt the edibility of either food type. It seems that crushing natural foods disrupted properties associated with their category membership, whereas processed foods did not. While explanations were spontaneous rather than forced choice, only close to 20% of older age groups and 5% of the youngest age group referred to a food's edibility. Considering the difficulty in producing explanations, this may be expected from the youngest age group but not from the older age groups, especially the adults. At least in this study, edibility was not the foremost reason that any age group used to determine its category membership boundaries. These results provide support for an age-related shift in the criteria used to determine category membership boundaries of natural foods compared to processed foods.

Theoretical implications

We believe these results add significantly to the growing body of research on children's conceptual development of food. The evidence points to food occupying a distinct conceptual space with its own developmental trajectory, within a domain-specific reasoning system. It expands the transformation paradigm in categorization research by applying it to the food domain, revealing nuanced developmental differences not captured by static categorization tasks. It opens a new developmental model for food cognition, showing that food concepts emerge early and are shaped by multiple, interacting ontological cues, including internal structure, function, origin, and level of human intervention.

Critically, our findings challenge the notion that children's food concepts, at least in the United States, are just extensions of natural kind or artifact concepts. Moreover, assuming the function of both types of foods are the same, the functional model does not fully explain the differences in category membership judgments for processed and natural foods by the older age groups. These results support the hybrid model, one in which children develop domain-specific causal-explanatory models that integrate knowledge about an item's origins, internal structure, and level of human intervention. The influence of these factors are weighted differently based on the type of food, revealing sophisticated, flexible reasoning skills. Furthermore, the developmental trajectory we observed demonstrates growth in children's conceptual understanding of food. Four- and five-year-olds' strategies appear to focus more narrowly than older children, reflecting limited causal knowledge and a reliance on perceptual or single-feature reasoning. By age six or seven, children appear to enter a transitional phase in which their judgments begin to incorporate multiple dimensions. This shift likely reflects both cognitive development (e.g., improved ability to coordinate multiple properties) and experiential factors, such as greater autonomy in food-related decisions and increased exposure to a wider variety of foods. For example, being privy to or participating in food preparation and shopping has been shown to deepen children's understanding of the causal processes behind food production and transformation (Girgis & Nguyen, 2018; Lafraire et al., 2016b).

Historical reasoning also supports the developmental trajectory, considering not only what a food currently is but also what it was before becoming part of the human food chain. For example, natural foods may be conceptualized as having once been living entities (part of a plant or animal), which remains relevant even when they are at the supermarket (Gelman & Kremer, 1991; Gelman, 2003). In contrast, processed foods, whose identity is based on human transformation, may be evaluated more in terms of functional continuity than biological history. Thus, the observed age-related differences in food categorization may emerge from a confluence of domain-specific conceptual growth, experience-based learning, and broader cognitive shifts toward integrating causal, historical, and functional information into category judgments. These findings call for a new developmental framework of food cognition, one that situates food as a meaningful, complex, and distinct category within children's broader conceptual development.

Limitations and future directions

An alternative explanation for differences in category membership between natural and processed foods is that the outsides of the processed foods are more likely to be edible, such as the outside of cheese or chocolate. While children and adults in the United States may have more experience with the outsides of processed foods being edible after removing the insides, the outsides of all the natural foods were also edible, including the shell of the shrimp and egg (as noted in multiple online sites, including safety guidelines on the Food and Drug Administration's website [FDA]). There are a few reasons to be cautious, as the only difference between processed and natural foods is familiarity with edible outsides for the crushed processed food. The first is the low number of explanations that are specific to edibility, and the second is that older children and adults, with more experience with food, judged processed and natural foods category membership differently after the crush transformation. In addition, there were no differences in category membership judgments between the food types after the melting transformation, yet melting shrimp and eggs is unusual. Exploring aspects of edibility as a functional property, however, is a vital next step in future research to more fully understand how these foods are categorized.

A possible limitation is that differences in category membership judgments may be due to some of the processed foods being considered substances, while natural foods were whole objects. Substances are harder to destroy because one has to destroy the smallest part of them, which are the molecules they are made up of, unlike a whole object, where destroying functional or essential properties is enough to destroy the object itself (see Rips & Hespos, 2015, for a review of substances and objects). While we were careful to select cohesive foods with distinct boundaries, such that none were liquid or amorphous and all had firm edges, the cheese, chocolate, and bread are made up of the same substance throughout. Yet, inherent to the makeup of processed foods is that they are combined with other ingredients, often containing additives, which can only be made through industrial processing, and contain a minimum, if any, whole foods (Monteiro et al., 2019). Future research should more fully explore the relationship between properties of a substance and properties of processed foods as it pertains to category membership judgments.

Although research assistants were trained to monitor for potential response bias, this could be a possible explanation for some of the responses, since there were no trials with an objectively correct answer to verify that participants were paying attention and understood the instructions. For example, in Study 1, approximately one-third of adult participants gave same-item responses to all stimuli. While no adults in Study 2 responded "same-item" to every stimulus, 20% did so for all stimuli shared with Study 1 (crushed broccoli, apple, ball, pencil, cactus, branch, chocolate, and bread). Because Study 2 included explanation prompts, which tend to reduce response bias, this pattern may reflect deliberate response choices. However, the absence of objectively correct trials remains a methodological limitation.

Finally, while these studies were tested in two different lower-middle and middle-class communities in the United States, it is imperative to include a broader sample from diverse backgrounds, especially with research in this domain. There are a number of social-, community-, and cultural-level factors that influence our interactions with foods, which should be explored before we can generalize with confidence that populations as a whole are categorizing foods in this manner.

Conclusion

The results support that even young children do not apply identical categorization strategies for foods compared to non-foods. Moreover, older children and adults do not apply a single, stable strategy for foods with different origins. There are important theoretical implications from these findings, as foods appear to be a hybrid of both natural and artifactual domains, as well as practical implications to inform developmental trends on specific properties that guide food selection. It underlies the complexity of this domain and provides a strong foundation for future research in understanding children's developing concepts of foods.

Acknowledgement

We thank the undergraduate research assistants with the Children's Learning Lab, Tania Gafanha, Stephanie Coulman, and Allison Fitzsimmons, for their work on this study. Many special thanks also to the schools and families that participated in this research.

Data Availability statement

The data and analytic code necessary to reproduce the analyses presented in this paper are publicly accessible on the Open Science Framework (OSF): https://osf.io/uednb/?view_only=843e556151bf440abe702e2481da7921. The materials were not preregistered.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.

ORCID

Helana Girgis http://orcid.org/0000-0002-2987-7039

References

Bailenson, J. N., Shum, M. S., Atran, S., Medin, D. L., & Coley, J. D. (2002). A bird's eye view: Biological categorization and reasoning within and across cultures. *Cognition*, *84*(1), 1–53. https://doi.org/10.1016/S0010-0277(02)00011-2

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. *Journal of Statistical Software*, *67*(1), 201–210. https://doi.org/10.48550/arXiv.1406.5823

Bloom, P. (2007). Water as an artifact kind. In E. Margolis & S. Laurence (Eds.), *Creations of the mind: Theories of artifacts and their representation* (pp. 150–156). Oxford University Press.

Carey, S. (1985). *Conceptual change in childhood*. MIT Press.

Casler, K., & Kelemen, D. (2005). Young children's rapid learning about artifacts. *Developmental Science*, *8*(6), 472–480. https://doi.org/10.1111/j.1467-7687.2005.00438.x

Chaigneau, S. E., & Barsalou, L. W. (2008). The role of function in categories. *Theoria et Historia Scientiarum*, *8*(1), 33–52. https://doi.org/10.12775/ths.2008.003

Cimpian, A., & Salomon, E. (2014). The inherence heuristic: An intuitive means of making sense of the world, and a potential precursor to psychological essentialism. *Behavioral and Brain Sciences*, *37*(5), 461–480. https://doi.org/10.1017/S0140525X13002197

DeJesus, J. M., Du, K. M., Shutts, K., & Kinzler, K. D. (2019). How information about what is "healthy" versus "unhealthy" impacts children's consumption of otherwise identical foods. *Journal of Experimental Psychology: General*, *148*(12), 2091–2103. https://doi.org/10.1037/xge0000588

Diesendruck, G. (2001). Essentialism in Brazilian children's extensions of animal names. *Developmental Psychology*, *37*(1), 49. https://doi.org/10.1037/0012-1649.37.1.49

Foinant, D., Lafraire, J., & Thibaut, J. P. (2021). Strength or nausea? Children's reasoning about the health consequences of food consumption. *Frontiers in Psychology*, *12*, 651889. https://doi.org/10.3389/fpsyg.2021.651889

Foinant, D., Lafraire, J., & Thibaut, J.-P. (2022). Relationships between executive functions and food rejection dispositions in young children. *Appetite*, *176*, 106102. https://doi.org/10.1016/j.appet.2022.106102

Gelman, S. A. (1988). The development of induction within natural kind and artifact categories. *Cognitive Psychology*, *20*(1), 65–95. https://doi.org/10.1016/0010-0285(88)90025-4

Gelman, S. A. (2023). Looking beyond the obvious. *American Psychologist*, *78*(5), 667. https://doi.org/10.1037/amp0001152

Gelman, S. A., & Bloom, P. (2000). Young children are sensitive to how an object was created when deciding what to name it. *Cognition*, *76*(2), 91–103. https://doi.org/10.1016/S0010-0277(00)00071-8

Gelman, S. A., & Kremer, K. E. (1991). Understanding natural cause: Children's explanations of how objects and their properties originate. *Child Development*, *62*(2), 396–414. https://doi.org/10.1111/j.1467-8624.1991.tb01540.x

Gelman, S. A., & Markman, E. M. (1986). Categories and induction in young children. *Cognition*, *23*(3), 183–209. https://doi.org/10.1016/0010-0277(86)90034-X

Gelman, S. A., & Wellman, H. M. (1991). Insides and essences: Early understandings of the non-obvious. *Cognition*, *38*(3), 213–244. https://doi.org/10.1016/0010-0277(91)90007-Q

German, T. P., & Johnson, S. C. (2002). Function and the origins of the design stance. *Journal of Cognition and Development*, *3*(3), 279–300. https://doi.org/10.1207/S15327647JCD0303_2

Gervits, F., Johanson, M., & Papafragou, A. (2023). Relevance and the role of labels in categorization. *Cognitive Science*, *47*(12), e13395. https://doi.org/10.1111/cogs.13395

Girgis, H., & Nguyen, S. P. (2018). Shape or substance? Children's strategy when labeling a food and its healthfulness. *Cognitive Development*, *48*, 289–301. https://doi.org/10.1016/j.cogdev.2018.08.003

Girgis, H., & Nguyen, S. P. (2020). Grown or made? Children's determination of the origins of natural versus processed foods. *Cognitive Development*, *56*, 100887. https://doi.org/10.1016/j.cogdev.2020.100887

Gopnik, A., & Sobel, D. M. (2000). Detecting blickets: How young children use information about novel causal powers in categorization and induction. *Child Development*, *71*(5), 1205–1222. https://doi.org/10.1111/1467-8624.00224

Gutheil, G., Bloom, P., Valderrama, N., & Freedman, R. (2004). The role of historical intuitions in children's and adults' naming of artifacts. *Cognition*, *91*(1), 23–42. https://doi.org/10.1016/S0010-0277(03)00165-3

Gutheil, G., & Rosengren, K. S. (1996). A rose by any other name: Preschoolers' understanding of individual identity across name and appearance changes. *The British Journal of Developmental Psychology*, *14*(4), 477–498. https://doi.org/10.1111/j.2044-835X.1996.tb00719.x

Hickling, A. K., & Gelman, S. A. (1995). How does your garden grow? Early conceptualization of seeds and their place in the plant growth cycle. *Child Development*, *66*(3), 856–876. https://doi.org/10.2307/1131955

Jaswal, V. K. (2006). Preschoolers favor the creator's label when reasoning about an artifact's function. *Cognition*, *99*(3), B83–B92. https://doi.org/10.1016/j.cognition.2005.07.006

Kalish, C. (1998). Reasons and causes: Children's understanding of conformity to social rules and physical laws. *Child Development*, *69*(3), 706–720. https://doi.org/10.1111/j.1467-8624.1998.tb06238.x

Keil, F. C. (1992). *Concepts, kinds, and cognitive development*. MIT Press.

Kelemen, D. (1999). Why are rocks pointy? Children's preference for teleological explanations of the natural world. *Developmental Psychology*, *35*(6), 1440–1452. https://doi.org/10.1037/0012-1649.35.6.1440

Kemler Nelson, D., Russell, R., Duke, N., & Jones, K. (2000). Two-year-olds will name artifacts by their functions. *Child Development*, *71*(5), 1271–1288. https://doi.org/10.1111/1467-8624.00228

Kimura, K., Hunley, S. B., & Namy, L. L. (2018). Children's use of comparison and function in novel object categorization. *Journal of Experimental Child Psychology*, *170*, 161–176. https://doi.org/10.1016/j.jecp.2017.12.016

Lafraire, J., Rioux, C., Giboreau, A., & Picard, D. (2016a). Food rejections in children: Cognitive and social/environmental factors involved in food neophobia and picky/fussy eating behavior. *Appetite*, *96*, 347–357. https://doi.org/10.1016/j.appet.2015.09.008

Lafraire, J., Rioux, C., Hamaoui Girgis, H., Nguyen, P. S., & Thibaut, J.-P. (2020). Food as a borderline domain of knowledge: The development of domain-specific inductive reasoning strategies in young children. *Cognitive Development*, *56*, 100946. https://doi.org/10.1016/j.cogdev.2020.100946

Lafraire, J., Rioux, C., Roque, J., Giboreau, A., & Picard, D. (2016b). Rapid categorization of food and nonfood items by 3- to 4-year-old children. *Food Quality and Preference*, *49*, 87–91. https://doi.org/10.1016/j.foodqual.2015.12.003

Malt, B. C. (1994). Water is not H_2O. *Cognitive Psychology*, *27*(1), 41–70. https://doi.org/10.1006/cogp.1994.1011

Marcario, J. F. (1991). Young children's use of color in classification: Foods and canonically colored objects. *Cognitive Development*, *6*(1), 17–46. https://doi.org/10.1016/0885-2014(91)90004-W

Menendez, D., Jiang, M. J., Edwards, K. M., Rosengren, K. S., & Alibali, M. W. (2020). Evaluating and communicating about the healthiness of foods: Predictors of parents' judgments and parent-child conversations. *Cognitive Development*, *55*, 100913. https://doi.org/10.1016/j.cogdev.2020.100913

Meunier, B., & Cordier, F. (2009). The role of feature type and causal status in 4-5-year-old children's biological categorizations. *Cognitive Development*, *24*(1), 34–48. https://doi.org/10.1016/j.cogdev.2008.05.003

Monteiro, C. A., Cannon, G., Lawrence, M., da Costa Louzada, M. L., & Machado, P. (2019, August 30). *Ultra-processed foods, diet quality, and health using the NOVA classification system [internet]*. Food and Agriculture Organization. https://openknowledge.fao.org/server/api/core/bitstreams/5277b379-0acb-4d97-a6a3-602774104629/content.

Murphy, G. (2004). *The big book of concepts*. MIT Press.

Nguyen, S. P. (2007). An Apple a day keeps the doctor away: Children's evaluative categories of food. *Appetite*, *48*(1), 114–118. https://doi.org/10.1016/j.appet.2006.06.001

Nguyen, S. P. (2020). From foods to artifacts: Children's evaluative and taxonomic categorization across multiple domains. *Cognitive Development*, *56*, 100894. https://doi.org/10.1016/j.cogdev.2020.100894

Nguyen, S. P., Gordon, C. L., Chevalier, T., & Girgis, H. (2016). Trust and doubt: An examination of children's decision to believe what they are told about food. *Journal of Experimental Child Psychology*, *144*, 66–83. https://doi.org/10.1016/j.jecp.2015.10.015

Nguyen, S. P., & Murphy, G. L. (2003). An Apple is more than just a fruit: Cross-classification in children's concepts. *Child Development*, *74*(6), 1783–1806. https://doi.org/10.1046/j.1467-8624.2003.00638.x

Opfer, J. E., & Bulloch, M. J. (2007). Causal relations drive young children's induction, naming, and categorization. *Cognition*, *105*(1), 206–217. https://doi.org/10.1016/j.cognition.2006.08.006

Owen, K., & Barnes, C. (2021). The development of categorization in early childhood: A review. *Early Child Development and Care*, *191*(1), 13–20. https://doi.org/10.1080/03004430.2019.1608193

Pickard, A., Thibaut, J.-P., & Lafraire, J. (2021). Strawberries and cream: The relationship between food rejection and thematic knowledge of food in young children. *Frontiers in Psychology*, *12*, 1–11. https://doi.org/10.3389/fpsyg.2021.626701

Pickard, A., Thibaut, J.-P., Phillppe, K., & Lafrarire, J. (2023). Poor conceptual knowledge in the food domain and food rejection disposition in 3- to 7-year-olds. *Journal of Experimental Child Psychology*, *226*, 105546. https://doi.org/10.1016/j.jecp.2022.105546

R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/

Rhodes, M., & Gelman, S. A. (2009). A developmental examination of the conceptual structure of animal, artifact, and human social categories across two cultural contexts. *Cognitive Psychology*, *59* (3), 244–274. https://doi.org/10.1016/j.cogpsych.2009.05.001

Rioux, C., Lafraire, J., & Picard, D. (2017a). The child food rejection scale: Development and validation of a new scale to assess food neophobia and pickiness among 2-to 7-year-old French children. *European Review of Applied Psychology*, *67*(2), 67–77. https://doi.org/10.1016/j.erap.2017.01.003

Rioux, C., Lafraire, J., & Picard, D. (2017b). Food rejection and the development of foodcategory-based induction in 2-6 years old children. *Journal of Cognitive Psychology*, *30*(1), 5–17. https://doi.org/10.1016/j.cogdev.2018.05.001/

Rioux, C., Lafraire, J., Picard, D., & Blissett, J. (2019). Food rejection in young children: Validation of the child food rejection scale in English and cross-cultural examination in the UK and France. *Food Quality and Preference*, *73*, 19–24. https://doi.org/10.1016/j.foodqual.2018.11.018

Rioux, C., Leglaye, L., & Lafraire, J. (2018). Inductive reasoning, food neophobia, and domain-specificity in preschoolers. *Cognitive Development*, *47*, 124–132. https://doi.org/10.1016/j.cogdev.2018.05.001

Rioux, C., Picard, D., & Lafraire, J. (2016). Food rejection and the development of food categorization in young children. *Cognitive Development*, *40*, 163–177. https://doi.org/10.1016/j.cogdev.2016.09.003

Rips, L. J., & Hespos, S. J. (2015). Divisions of the physical world: Concepts of objects and substances. *Psychological Bulletin*, *141*(4), 786–811. https://doi.org/10.1037/bul0000011

Rose, D., & Nichols, S. (2019). Teleological essentialism. *Cognitive Science*, *43*(4), e12725. https://doi.org/10.1111/cogs.12725

RStudio Team. (2016). *Rstudio: Integrated development for R*. RStudio, Inc. http://www.rstudio.com/

Sloutsky, V. M. (2018). Category learning and conceptual development. In J. T. Wixted & S. Ghetti (Eds.), *Stevens' handbook of experimental psychology and cognitive neuroscience* (4th ed., pp. 37–82). Wiley.

Springer, K., & Keil, F. C. (1991). Early differentiation of causal mechanisms appropriate to biological and nonbiological kinds. *Child Development*, *62*(4), 767–781. https://doi.org/10.2307/1131176

U.S. Census Bureau. (2023a, August). U.S. Census Bureau Quick Facts. https://www.census.gov/quickfacts/fact/table/oneontacitynewyork/PST045221

U.S. Census Bureau. (2023b, August). U.S. Census Bureau Quick Facts. https://data.census.gov/table?q=Galloway+township,+Atlantic+County,+New+Jersey

Waxman, S., Medin, D., & Ross, N. (2007). Folkbiological reasoning from a cross-cultural developmental perspective: Early essentialist notions are shaped by cultural beliefs. *Developmental Psychology*, *43*(2), 294. https://doi.org/10.1037/0012-1649.43.2.294

Wellman, H. M., & Gelman, S. A. (1992). Cognitive development: Foundational theories of core domains. *Annual Review of Psychology*, *43*(1), 337–375. https://doi.org/10.1146/annurev.ps.43.020192.002005

Appendix A

a. *Sample target category pictures*

Natural Food

Apple

Not Apple

Processed Food

Bread

Not Bread

Natural Kind

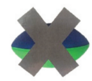
Branch

Not Branch

Artifact

Ball

Not Ball

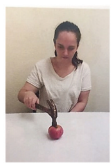


b. *Sample protocol and pictures for the crush transformation*

Picture 1

"So, see these are apples. You can find them in a garden. Things in a garden grow naturally in the ground."

Picture 2



"Now look what happens here. This person it is crushing it".

Picture 3

"Now it is crushed. Where does it go? "If it is an apple, then point to this picture (Apple Target picture), and if it is not an apple, point to this picture (Not Apple Target picture)."