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A time for a meal? Children's conceptions of short-term and long-term effects of foods

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ABSTRACT

From early ages, children build concepts of food categories, classify foods according to various points of view (e.g., taxonomic or thematic), and reason about them (e.g., Nguyen, 2008; Nguyen & Murphy, 2003). However, theory-based reasoning regarding food develop more slowly than categorization. Even adults refer to poorly-articulated explanatory concepts such as vitalism (Slaughter & Ting, 2010). In two experiments, we assessed 6-, 8-, 10-year-old children's understanding of short- and long-term effects of foods. We asked children to chose between series of long-term (eating quite often) and short-term (eating yesterday) effects of food. The key issue was whether six-year-old participants would distinguish between different time-based food effects or not. The latter is suggested by the vitalistic view according to which there is some vital power that is taken from food and water and makes humans active. Results showed that younger children could differentiate short- and long-term causes and effects of foods, even though less clearly than older children could. Results are discussed in terms of the development of the naive theories. Former results are reinterpreted in terms of the collected data.

1. Children's understanding of the role of food

Children's reasoning about foods and their properties is, to a large extent, related to developments in their underlying naive conceptions regarding biology (e.g., Inagaki & Hatano, 2002, 2004). Thus, the study of children's knowledge of foods is related to the substantial body of research devoted to children's naive theory of biology, including the early distinction between natural kinds and artifacts and children's understanding of biological processes (see Gelman & Kalish, 2006; Inagaki & Hatano, 2006; Wellman & Gelman, 1998, for reviews). Recent papers have stressed the practical implications of these naive theories, showing that young children benefited from structured theory-based interventions that contribute to eating-behavior changes (Kelemen, 2019; Weisman & Markman, 2017). This issue is a timely one given the growing prevalence of overweight and obesity in children in many Western countries and beyond that has been documented by many studies (e.g., Centers for Disease Control & Prevention, 2015; World Health Organization, 2015a, 2015b), making a strong case for biologically-informed education regarding the effects of foods.

A large number of nutrition education programs are designed mainly to present children with a list of basic facts without embedding them into children's emerging naive theory of biology (see Gripshover & Markman, 2013; Nguyen, McCullough, & Noble, 2011; Weisman & Markman, 2017, for discussions). However, theory-based interventions are more effective than mere exposure to a list of facts (Weisman & Markman, 2017). Thus, this is a strong incentive to gain more knowledge about children's conceptions

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regarding food-related biological processes. In this respect, biological processes such as growth, illness, and organ functioning that have been studied within the context of children's naive theory of biology are highly relevant to nutritional issues. In the following sections, we summarize the development of children's knowledge regarding food and relations with health and related properties. After briefly mentioning induction studies, we will review the development of sophisticated knowledge regarding the effects of food and their relation to general explanatory mechanisms.

1.1. *Specific and general explanatory mechanisms for foods*

1.1.1. *Food categories as a basis for induction*

A first source of evidence regarding young children's early knowledge of food properties and their effects comes from induction studies that require generalizing properties that have first been associated with one food to other novel foods. Nguyen (2007) has shown that three-years olds are able to classify healthy and unhealthy foods correctly. Also, children use *evaluative* food categories (healthy or junk) productively in the sense that they generalize biological properties to other pieces of food belonging to the same evaluative category. In Nguyen (2008), experiment 2) children could use evaluative food categories to reason about nutrition despite their taxonomic and contextual (script) heterogeneity (e.g., healthy foods include fruits, beverages, types of meat, dairies, breakfast/lunch foods). They generalized an unknown bodily property first associated to a food (e.g. unhealthy food such as Cheetos) to an evaluative category match (e.g., ice cream, another unhealthy food) rather to a non-category match (e.g., fish, a healthy food) (see also Rioux, Leglaye, & Lafraire, 2018, for induction studies with non-evaluative taxonomic food categories; Thibaut, Nguyen, & Murphy, 2016, for psychological and biological properties).

1.1.2. *Understanding food biological background and food mechanisms*

Do these induction skills mean that children understand relations between food and targeted biological outputs? This question can be divided into two related questions: one regarding the relationship between food and general biological processes associated with life and health, the other targeted at the mechanisms and consequences of food consumption. We will address them in this order.

As far as general biological mechanisms are concerned, studies have examined the nature of children's understanding of the general purpose of eating and its effects. Inagaki and Hatano (1993, 2002) for instance, showed that 6-year-olds favor vitalistic causal explanations, that is they assume that there is a vital power or life force taken from food and water that makes humans active, prevents them from being taken ill, and enables them to grow. Importantly, when they were asked why we eat every day, or what are the effects of food, children referred to the vital force of food (e.g., they chose an explanation such as "Because our stomach takes in vital power from the food.") over an intentional cause ("Because our stomach wants it") or a more directly relevant physiological cause ("Because we take the food into our body after its form is changed in the stomach and bowels"). According to Inagaki and Hatano, this type of explanation that they called *vitalistic* characterized children around six years of age. *Vitalism* looks like a physiological cause except that it is mechanistically underspecified. In a follow-up study, Slaughter and Ting (2010) found evidence that vitalistic explanations increased between the ages of 5 and 8 years, but remained a significant percentage of the explanations provided by adults even though mechanistic explanations (e.g., movement of substances through the body) increased with age. They compared the justifications of different age groups, including adolescents and adults, for four food-related questions: the effects of the components of food, the purpose of eating, the effects of various quantities of foods, and the effects of an unbalanced diet. Participants' justifications were coded as vitalist (e.g, vital power), psychological (e.g., desires, feelings), elaborated physiological reasoning (i.e., interactions between foods and bodily functions), or less elaborated reasoning such as biological associationism (e.g., linking foods with a general biological output). As expected, physiological reasoning increased with age in the four investigated food questions, but interestingly, for the four questions, vitalism remained a strong contender for participants older than ten years old. Slaugther and Ting's data (see also, Miller & Bartsch, 1997; Morris, Taplin, & Gelman, 2000) suggest that even adults find articulating biological explanatory mechanisms and real physiological phenomena difficult. According to Gottfried and Gelman (2005) vital energy might act as a causal placeholder in the explanation of biological properties: "Children recognize the need for an inherent causal mechanism for behaviors of living things but lack specificity as to what that mechanism is" (p. 154).

Do vitalistic explanations imply that children (and adults) are unable to articulate more specific explanations connecting food and targeted biological outputs? Using general explanatory principles such as vitalism does not mean that children are not aware of any specific mechanism. The fact that children did not choose a mechanistic explanation such as a precise digestion mechanism in a list of possibilities and chose the vitalist explanation in Inagaki and Hatano (2002) does not prove that they were unaware of *any* biological mechanism.

1.1.3. *Children's understanding of food-related physiological mechanisms*

Several studies have investigated children's knowledge of specific biological mechanisms. In these studies, children are generally confronted with simple situations involving pieces of food and they are asked to anticipate the results of diets including the food. Wellman and Johnson (1982) examined children's (6-, 9-, 12-year olds) understanding of the consequences of different types of diets. They introduced pairs of characters each differing on one dimension: health, energy, height, strength and weight (e.g., one is overweight and the other is underweight) and asked them what might have caused the difference between these two characters. The three age groups mentioned diet as the main justification for the differences between the characters. However, younger children focused more on the *quantity* of food whereas older children mentioned the *quality* and/or the specificity of the food eaten. In a second task on the consequences different diets might have on twins, 6-year-olds mistakenly associated the amount of food consumed with their height, thinking that eating large quantities increases weight, regardless of the type of food, and generalized water overconsumption to height, energy, and weight. All age groups considered vegetables as positive for health. Older children thought that vegetables have no effect on height whereas younger children thought vegetables do. Finally, the three groups acknowledged that a restricted diet (e.g., eating only one food) is unhealthy (see Guérin & Thibaut, 2008; Raman, 2014; see Toyama, 2000, on the role of digestion and the necessity of a varied diet). Raman (2014) assessed the impact of healthy and unhealthy foods on height and weight. Preschoolers thought that both healthy and unhealthy foods would result in growing taller and more overweight (see also Au, Romo, & DeWitt, 1999, for the notion of the input-output concept). A shift appeared for nine-year olds who made a differential attribution of the impact of food on growth. Raman, Cosby, and Hodroj (2018)) report a study in which children had to deduce which food(s) one character ate. In Raman (2011), preschoolers and second graders thought that psychobiological properties such as the "yuckiness" of food affected biological mechanisms such as growth (e.g., height and weight) but did not associate these psychobiological properties with illness. For example, they thought that height would be more affected by a "yummy" healthy food than a "yucky" healthy food (see also Guérin & Thibaut, 2008; McKinley et al., 2005; see Thibaut, 1999, for an overview)

Two main issues remains to be discussed. First, even though, preschoolers can connect healthy and unhealthy food categories consistently to different outputs, more specific mechanisms related to food (e.g., causes of overweight, discrimination regarding the role of different categories of food) do not seem to be understood by children under seven. Second, however, even adults refer to very general biological principles like vitalism when asked to explain food effects, that is they use it as a causal placeholder when a more specific and unavailable explanation is required (Gottfried and Gelman, 2005).

Physiological mechanisms occur in their own time scale, short or long. A big cake does not cause a person to immediately gain weight, whereas a heavy meal might cause indigestion in the following hours. When dealing with food properties, studies often seem to assume that healthy and unhealthy are general properties and do not refer to their underlying properties which include temporal aspects. The purpose of the present research is to study to what extent young children acknowledge this temporal dimension, dissociating short- and long-term effects and/or short- and long-term causes. The issue is potentially important because healthy eating habits most often refer to long-term effects of foods ("eating more fruits, less sugar, or less fat" refers to behaviors that are recommended as a daily diet).

Understanding the duration dimensions of physiological properties associated with general life mechanisms requires participants to understand that physiological processes have a duration. In turn, these processes require an approximate representation of duration at least in terms of short-term causes or effects (say, within a day or two) and long-term causes or effects (weeks and months). As for time estimation, Friedman and Kemp (1998) showed that even 4- and 5-year-olds were able to differentiate durations such as yesterday, last weekend, or last summer. Five-year-olds are also able to correctly situate daily activities but also events at various distances on a timeline (Friedman, 1992, 2000 & 2002). Thus, in these studies, even four-year-olds could reliably represent a set of daily-activities and annual events on a reference axis, which relies on precise temporal anchoring of successive events. As for biological processes, evidence for children's understanding of their temporal grounding is mixed. Kalish (1997) found that most preschoolers did not recognize that bodily responses to contamination would occur immediately on contact even though they were able to understand duration in the case of non-biological events. Williams and Binnie (2002) found that even seven-year-old children did not know the notion of an incubation period and expected that consequences of contagious and non-contagious diseases would follow directly. Raman and Gelman (2007) found that preschoolers expect illnesses to manifest themselves immediately whereas they acknowledged a greater temporal gap between medication and the cure. In their experiment, children were asked whether the consequences would occur right away, a little later, much later the same day, or the next day, hence, in a short reference time-scale. In a study on the effects of sedentary versus physical activities on weight, Raman (2019) showed that preschoolers did not understand the impact of short-term and long-term activities whereas 7-year-olds were significantly better than preschoolers when assessing the impact of both types of activities on weight but were significantly different from adults on sedentary activities. In sum, up to seven years of age, children seem to encounter difficulties when reasoning about biological processes. However, this lack of knowledge of the temporal dimensions might be restricted to the targeted physiological processes under scrutiny.

1.2. Aims and hypotheses

Six years of age has also been described as a critical age in the occurrence of general explanatory mechanisms such as vitalism. In this context, Inagaki and Hatano (1993) have shown that for 6-year-old children foods play a central role in their vitalistic reasoning. However, vitalism, according to Morris et al. (2000) might be a default explanatory notion when a more detailed and specific mechanism is not available. Also, former studies (e.g., Nguyen, 2007) take healthy or junk as general timeless food properties. Given that the time-course of food effects, short- or long-term, differs depending on the type of physiological process, it is necessary to study children's understanding of this time-course. In two experiments, we will study children aged 6 to 10 and manipulate the duration of biological phenomena caused by food ingestion (short- or long-term effects such as stomach ache or being overweight) and the duration of the food intake taken as a cause (e.g., eating foods high in fat once or on a regular basis). We focused on 6-to-10-year-old children on the basis of the existing evidence showing that younger children have a hard time explaining biological phenomena. Experiment 1 was a yes-no task, in which three age groups of children (6 – 7-year olds, 8 – 9-year olds, 10 – 11-year olds) had to accept or reject a statement about a consequence of food ingestion on biological phenomena which were categorized as short-term or long-term. Experiment 2 was a forced-choice design in which children had to choose between two "types" of food consumption (long-term or short-term) on a given effect (Experiment 2A) or to choose between two possible consequences of consumption of a given food taken as a cause (Experiment2B).

1.2.1. Hypotheses

H1. A general explanatory cognitive mechanism such as vitalism predicts that young children will mix up short- and long-term influences of foods. If young children's answers are based on general vitalistic principles, "don't know" answers or unspecified references to food qualities (e.g., they are good for my body) should characterize their justifications profile.

H2. In general, we predict better performance with age, with older children providing answers driven by a better understanding of time-based food processes. Justifications should refer more often to temporal processes in older groups than younger children.

H3. The availability and salience of incorrect or partial knowledge such as the healthy-unhealthy classification system of food categories (Nguyen, 2008) should lead to mostly quality-based justifications rather than to time-related explanations.

H4. Short-term food-related events might be better understood because they correspond to food categories as they are reified in children's representations: a bad food or dish gives a direct and immediate output whereby long-term effects are very progressive and are not perceived. Long-term effects might be poorly understood because they are contaminated by short-term events.

2. Experiment 1

Experiment 1 assessed children's knowledge of the time course of food consumption on physiological processes. We contrasted situations defined by short-term effects and causes and defined by long-term effects and causes. Long-term causes and effects were defined as situations in which the physiological output (e.g., being fit or overweight) is the result of long-term consumption of healthy or unhealthy food (e.g., eating vegetables or big cakes on a regular basis). Short-term effects and causes were defined as effects that result from short-term causes (e.g., indigestion is caused by something eaten on the same day or the day before, but not a week before). We also designed a condition that was called long-term-effect_short-term-cause that should normally be rejected, as long-term effects are mentioned (e.g., being in good health) as a consequence of a short-term cause (e.g., eating vegetables once).

2.1. Methods

2.1.1. Participants

Participants were sixteen 6 − 7-year olds (5 girls; M = 6;94, range 6;4 to 7;9), twenty 8 − 9-year olds (11 girls; M = 8;9, range 8;3 to 9;6) and fifteen 10 − 11-year olds (8 girls; M = 11;0, range 10;3 to 11;9). They spoke French as their native language. They were predominately Caucasian and were recruited in schools from middle-class areas. Informed consent was obtained from their school and their parents. The procedure followed standard institutional ethics board guidelines for research on humans.

2.1.2. Materials

We designed three sets of questions, each comprising three YES-NO questions. Each set corresponded to different temporal durations of food-related effects and causes. The three types of questions were ShortE_ShortC for short-term effects and short-term causes, LongE_ShortC for long-term effects and short-term causes, and LongE_LongC for long-term effects and long-term causes. Short-term and long-term effects were defined based on their duration and biological properties. That is, short-term effects resulted from sudden changes (e.g., an acute tummy ache). Short-term causes were defined as events that happened only one time recently or some time ago (e.g., yesterday, or many years ago, Tom ate an apple). Long-term effects were defined as effects resulting from changes that take time (e.g., gaining weight), and long-term causes refer to events that happened repeatedly before (e.g., to eat big cakes every day). All the questions were associated with biological properties related to behaviors involving food consumption. The resulting 9 items are listed in Table 1.

2.1.3. Procedure

Children were tested at school in a quiet room. The three types of questions were presented in random order. The experimenter and the child were sitting opposite each other. First, the experimenter made the child feel comfortable. The instructions were as

Table 1

The three categories of items used in Experiment 1

ShortE_ShortC	Benjamin's belly is painful. Do you think it is because he ate a cake last week?
	This girl (showing a picture) tummy hurts now. Do you think it might be because she ate a big lunch yesterday?
	Justin is in great shape today. Do you think it is because he ate fruits yesterday?
LongE_ShortC	I saw Mathieu. He is fat. Do you think it is because he ate a pie today?
	Elsa is thin (showing a picture). Do you think she is thin because she ate a lot of vegetables this morning?
	Olga is going to the hospital because for a long time her tummy hurts. Do you think it is because she ate a big cake when she was young?
LongE_LongC	Madeleine is fat. Do you think it is because she eats big cakes every day?
	Julien is in great shape, in good health. Do you think it is because he often eats spinach, carrot, and many other vegetables?
	Julie has a disease in her belly for a long time. Do you think that it might be because she ate a lot of fatty foods every day?

Note. ShortE_ShortC stands for short-term effect and short-term cause; LongE_ShortC for long-term effect and short-term cause; LongE_LongC for long-term effect and long-term cause.

Table 2

Duration	Mean	*SD*
ShortE_ShortC	.68**	.30
LongE_ShortC	.72***	.32
LongE_LongC	.90***	.18
Total	.77***	.19

Note. * for p < .01; ** for p < 0.001; *** for p < 0.0001. Wilcoxon tests compared children's scores against chance (0.5). *p*-values are corrected for multiple tests (significance level is at .01).

follows: "I am going to ask you a few questions about food and you will need to answer what you think, either yes or no. There are no good and bad answers, I want to know what *you* think for each question I will ask. Listen carefully". In order to illustrate the situation, one picture representing a child was chosen in a set of two pictures (a boy and a girl) and introduced as the character mentioned in the statement (e.g., a boy for "Mathieu"). If I tell you something that you do not understand, tell me. I will explain what I mean". After each answer, children were asked to provide a justification for their answer (i.e. "why did you answer this" or "why did you choose this solution"). No feedback followed children's answers.

2.2. Results

To test our hypotheses, we fitted three generalized linear models to the data with the children's answers (correct or incorrect, from a scientific point of view) as the dependent measure. As shown in Table 3, the models were constructed by iteratively adding predictive variables to the null model (M0, the intercept and no predictor). To identify the variables that were most predictive of performance variations among children, we carried out a stepwise procedure using the AIC (Akaike Information Criterion, Hu, 2007), as our criterion for model selection. The predictive variables were Age (6 − 7-year olds, 8 − 9-year olds, and 10 − 11-year olds), and Duration (ShortE_ShortC, LongE_ShortC, and LongE_LongC). The interaction between Age and Duration was also added to the model.

Overall, children were above chance level (as attested by a Wilcoxon test, M = .77, *SD* = .19, W = 1276, $p < .0001$, see Table 2). Children tended to answer correctly, providing the expected answer. The same pattern was found for each Duration (see Table 2).

M3 explained 26.97 % proportion of the variation across our sample, as demonstrated by the adjusted R^2. It revealed a main effect of Age (χ^2 (2) = 14.768, $p < .001$). Post-hoc Tukey comparisons revealed that 6 − 7-year olds performance (*M* = .63, *SD* = .13) were significantly lower than 8 − 9-year olds (*M* = .80, *SD* = .19, $p = .014$) and 10 − 11-year olds' (*M* = .86, *SD* = .17, $p < .001$) which did not differ one from the other. There was also a main effect of Duration (χ^2 (2) = 22.924, $p < .001$), children's performance were significantly better for LongE_LongC questions (*M* = .90, *SD* = .18) than for ShortE_ShortC (*M* = .68, *SD* = .30, $p < .001$) and LongE_LongC questions (*M* = .71, *SD* = .32, $p < .001$). The most interesting result was the interaction between Age and Duration (χ^2 (4) = 14.181, $p = .005$). A Tukey a posteriori test revealed no difference between the three groups of children in the LongE_LongC condition, whereas 6 − 7-year olds' performance were significantly lower than the two other age groups for LongE_ShortC and ShortE_ShortC questions (all $p < .05$) (see Fig. 1). See Table 14 for all the mean performance by experiment, age and conditions.

2.2.1. Justifications analysis

We analyzed children's justifications (n = 321) of their answers. We defined four categories of justifications (see Table 4 for examples; by Age and Duration, see Table 5). T + corresponded to a correct explanation of the time course of the depicted event; T- referred to time but was inconsistent with the depicted event; QL referred to qualities of the foods (i.e., QL; reference to food intrinsic characteristics); QN referred to food quantity (i.e., QN; reference to the quantity of ingested foods) (see Table 5). 29 % of children's justifications could not be coded and were not considered further (30 %, 47 % and 13 % in 6 − 7, 8 − 9, and 10 − 11-year-olds respectively). Most uncodable justifications were absences of explanation. The experimenter did not insist to get one. Otherwise, uncodable justifications were usually idiosyncratic comments associated with children themselves or the depicted character, such as "I eat these cakes as well and I never felt any pain". "She should have eaten fruits instead". "When we are young, we are forbidden to eat cakes" or irrelevant explanations such as "It is because she slept well" or "Because he likes its taste". Finally, two independent judges coded the justifications. The second judge coded a third of the set of justifications (n = 138). A Cohen's Kappa coefficient gave an agreement score of .83 which is "very good agreement" according to Altman (1990).

We expect T + explanations reflecting a deeper understanding of the time course of food effects. A chi-square test of

Table 3

Model		AIC	Deviance	*p*-value
M0	1	493.70	489.70	
M1	+ Duration	470.38	462.38	< .001
M2	+ Duration + Age	459.93	447.93	< .001
M3	**+ Duration * Age**	**440.92**	**420.92**	**< .001**

Note. The Deviance column indicates the increase in explained variability. For example, the residual deviance for M1 was 462.38, while the residual deviance for M2 was 447.93, a difference of 14.45.

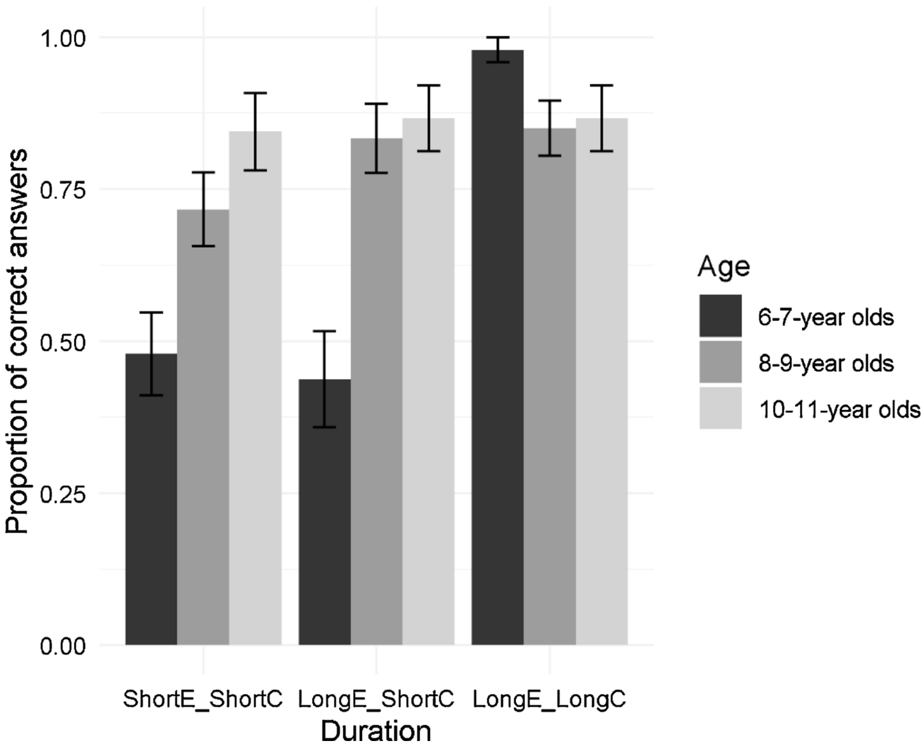

Fig. 1. *Note*. Proportion of correct answers for each age group for the three types of questions. Error bars are *SEM*. ShortE_ShortC stands for short-term effect and short-term cause; LongE_ShortC for long-term effect and short-term cause; LongE_LongC for long-term effect and long-term cause.

Table 4

Examples of children's explanations for each of the four categories of justifications

T+	- Tummy ache would have appeared last week, not a week later. - We do not get fat in a day.
T-	- He should have eaten the fruit today. - We need to eat vegetables at each meal except in the morning.
QL	- Cakes make you fat. - Vegetables give plenty of vitamins.
QN	- She ate less to get leaner. - He ate a lot so he gained weight.

Note. T + stands for "correct explanation based on time"; T- stands for "incorrect explanation based on time", QL stands "quality of the food", QN stands for "quantity of the food(s).

Table 5

Percentage of each justification categories by Age and temporal duration

Duration	ShortE_ShortC				LongE_ShortC				LongE_LongC			
Justification	T+	T-	QL	QN	T+	T-	QL	QN	T+	T-	QL	QN
6 − 7-year olds	30.0	5.0	35.0	30.0	27.5	7.5	40.0	25.0	33.3	0.0	46.7	20.0
8 − 9-year olds	65.7	2.9	11.4	20.0	60.0	5.7	8.6	25.7	22.7	0.0	63.7	13.6
10 − 11-year olds	62.8	2.3	7.0	27.9	58.1	0.0	16.3	25.6	18.2	0.0	60.6	21.2

independence examined the relation between Types of justification and Age, for each of the three types of duration separately. For ShortE_ShortC questions, it showed that the relation was significant, χ^2 (6) = 25.12, $p < .001$. Post-hoc Chi-square showed that for both 8 − 9-year olds and 10 − 11-year olds distribution compared to 6 − 7-year olds, age, and type of justifications were significantly related. For 6 − 7-year olds versus 8 − 9-year olds (χ^2 (3) = 10.37, p = .016) and, for 6 − 7-year olds versus 10 − 11-year olds (χ^2 (3) = 14.77, p = .002) the relation was also significant. Table 5 suggests that this is due to a larger number of T + in the 10 − 11-year olds and 8 − 9-year olds groups than in 6 − 7-year olds children for whom correct references to time explanations (T+), quantity (QN) and quality (QL) were evenly distributed. The same pattern of answers was obtained for LongE_ShortC questions, the relation between Types of justification and Age was also significant, χ^2 (6) = 17.83, p = .007. For 6−7-year: 8−9-year olds (χ^2 (3) = 11.99, p = .007) and 10−11-year olds (χ^2 (3) = 11.92, p = .008). As shown by Table 5, this seems to be due to the lower number of T + and the larger number of references to quantity (QN) in the younger group. For LongE_LongC questions, the relation between Types of justification and Age was not significant, χ^2 (6) = 2.75, p = .60. This is due to the fact that the three groups of participants mostly referred to the quality of foods rather than to time-based explanations which tended to decrease with age (see discussion).

2.3. Discussion

This experiment tested children's understanding of long or short-term causes on short-term or long-term effects. The most important result is that the three groups had a high level of performance for statements describing a long-term effect with long-term causes (and required a "yes" answer). 8−9-year olds and 10−11-year olds' performance was also very high when long-term effects were confronted with short-term causes (and required a "no" answer). Statements involving short-term effects for short-term cause (and required a "no" answer) were better answered with age. Overall, children first understand that long-term food effects require long-term causes rather than short-term causes. The younger group had more difficulties with short-term causes when they involved both short- and long-term effects. Indeed, the analysis of the justifications in the short-term and long-term effects with short-term causes conditions shows that the number of quality and quantity related justifications decreased with age in favor of correct references to time justifications. Note, that the majority of younger children's time-related explanations were correct. Interestingly, in the long-term effect with long-term cause conditions, the number of references to quality increased with age while the number of correct references of time explanations decreased. It seems that participants took the long-term dimension for granted because the food was ingested on a regular basis, and explained the property associated with the character in terms of the quality of foods rather than to its quantity.

Another difficulty with short-term effects is to define what a small temporal scale for short-term effects is. Indeed, the minimum number of repetitions of food intakes in order to have a significant effect, the interaction between the number of repetitions and quantity, are not straightforward, especially for children. Thus, for children, referring to food quality might be an easy fall-back strategy given that, as shown by Nguyen (2007), four-year-olds are already aware of which foods are healthy or unhealthy and can use this distinction productively.

Younger children's difficulties with short-term statements might result from the fact that these statements generally required a negative answer, whereas long-term statements required a "yes" response. A bias in favor of "yes" might explain the high level of performance in the long-term statements and the low level of performance in the short-term statements. A yes-bias has been observed in some situations and can be interpreted as a desire to please the experimenter. However, this bias cannot explain our data since it predicts a majority of incorrect answers which would be significantly lower than 50 %, the observed level of performance. The justification profile is also inconsistent with the yes-bias. In the case of a systematic bias, participants' answers would not be motivated by any underlying conception and their justifications would not be meaningful. In fact, participants produced correct time-related explanations in a significant percentage of cases or explanations based on the quality of food. These two categories of justifications constituted between 65% to 80% of the younger group's justifications. In fact, they are sensible justifications of food effects.

In sum, Experiment 1 revealed a progressive differentiation of short- and long-term causes and effects with age. In the following experiment, we want to distinguish children's understanding of "food as a cause" and "effects of foods" with a forced-choice paradigm. That will lead to the following distinction. Starting with the description of an effect such as "Pierre is overweight", children would have to figure out what caused this effect. On the other end, starting with a cause (e.g., he eats big cakes every day) we can ask what would be the consequences of this food-related behavior. In order to make the options clear, children will be asked to choose between two time options, a short- and long-term one.

3. Experiment 2A: Long-term and short-term causes

Experiment 1 revealed that younger children had more difficulties with short-term problems (ShortE_ShortC) and mixed problems (LongE_ShortC) than with long-term statements (LongE_LongC). In Experiment 1, all the statements started with an effect, followed by a possible causal explanation that participants had to evaluate.

The purpose of Experiment 2 is to dissociate the study of the causes and effects of foods. Statements will start either with a cause and participants will have to assess which one of two options is the correct effect, or with an effect and participants will have to assess which option might be the correct cause. Experiment 2 has two sections with the same participants despite the fact that both sections took place in the same session. We present them separately for the sake of clarity. Also, the two parts were conceived to be complementary rather than equivalent. Methodological equivalence would also have required additional control (e.g., length and difficulty of the statements).

The first one (Experiment 2A) investigates children's understanding of effects, long-term and short-term. Experiment 2B investigates children's understanding of the causal relation binding a cause with possible effects. To make the task more understandable, we also introduced pictures of the characters referred to in the sentences and we provided a picture of a timeline while explaining the meaning of long-term and short-term to the participants.

Table 6

The three categories of items used in Experiment 2A

ShortE_RecentC-DistantC	Whose tummy hurts today? Bob who ate a big lunch yesterday or Jules who ate a big lunch last week?
	*Who has more strength? Arnaud who ate a big steak a long time ago, or Olivier who ate a steak at dinner yesterday?
LongE_DistantC-LongC	Whose tummy hurts for a long time, many days? Michel who ate a big cake when he was a young child, or José who often eats cakes?
	Who gains more weight? Geraldine who ate oily fries last week, or Lea who eats oily fries every day for many weeks now?
LongE_RecentC-LongC	Who is in better shape? Josephine who ate fruit this morning, or Clara who eats fruits every day?
	Who is enjoying better health? Gaëlle who ate fruits this morning, or Charlotte who often eats fruits but not today?

Note. ShortE stands for “short-term effect”, LongE stands for “long-term effect”, RecentC stands for “recent short-term cause”, DistantC stands for “distant short-term cause”, and LongC stands for “long-term cause”.

* “has more strength” is the literal translation of the French “a plus de force”; it also conveys the idea of “has more energy”.

3.1. Method

3.1.1. Participants

Children were recruited at their school from the same population as Study 1. However, they did not participate in Experiment 1. There were fifteen 6 – 7-year olds (6 girls; M = 6;57, range 6;1–7;1), thirteen 8 – 9-year olds (4 girls; M = 8;6, range 7;9 – 9;11) and fifteen 10 – 11-year olds (8 girls; M = 10;6, range 10;1–11;1).

3.1.2. Materials

The experiment was a forced-choice questionnaire. The questionnaire (see Table 6) investigated children’s reasoning on long-term or short-term causes of long-term or short-term effects (e.g., Who gained the most weight? Géraldine who ate fatty French fries last week, or Léa who has eaten fatty French fries every day for several weeks?). There were three categories of statements, (1) ShortE_RecentC-DistantC, a short-term effect (e.g., tummy pain today) with two contrast options as short-term causes, a recent one (RecentC) (e.g., yesterday meal) or a more distant one, DistantC (e.g., last week heavy meal); (2) LongE_DistantC-LongC trials, long-term effects (e.g., becoming overweight) caused by short-term cause but a distant one (DistantC, a big cake last week) or long-term cause (e.g., eating cakes regularly); (3) LongE_RecentC-LongC, that is, again, a long-term effect with either a long-term cause (e.g., “who is in better health?”) or a recent short-term cause (e.g., one cake this morning, RecentC). We also used a set of pictures depicting characters, two girls and two boys, that were used to illustrate the designated characters. Finally, a drawing of a timeline was used to anchor the temporal references that were used in the experiment (e.g., to illustrate the respective positions of yesterday compared to last week, or to a long time ago). Prior works (Friedman, 2000,2002) have shown that children aged five can use this type of representation accurately.

3.1.3. Procedure

As in Experiment 1, the experimenter started with: “I am going to ask you a few questions about food and you will need to answer what you think. There are no good and bad answers, I just want to know your opinion, so you tell me what you really think. From time to time, I will show you some pictures to help you understand the question I ask. I will show you pictures of the two characters I’m talking about. Listen and look closely and if there is anything that you do not understand, tell me.” In the beginning, the experimenter introduced a timeline that was kept visible on a table and explained to the child what the time expressions used in the experiment meant using this timeline. Children were told that “what I’m going to tell you could be a long time ago that is months ago", “lots of days ago”, or “yesterday”, "a short while ago” or other expressions that children could understand. The experimenter showed the timeline, and explained, where “today” or “yesterday” or long durations, such as “lots of days”, or long-term durations such as “many days ago and also today”. Then, the experimenter asked all the questions in random order. The experimenter recorded the answers and for each question, asked the child to explain his/her answer.

3.2. Results

As in Experiment 1, to select the predictive variables that best-explained variations in children’s answers, we used the AIC as the criterion for model selection in a stepwise procedure. Our predictive variables were Age (6 – 7-year olds, 8 – 9-year olds and 10 – 11-year olds), and Duration (ShortE_RecentC-DistantC, LongE_DistantC-LongE, and LongE_RecentC-LongE). The interaction between Age and Duration was not selected because the corresponding model (M3) did not provide a better data fit than model M2 (see Table 8).

Overall, children were significantly above chance (as attested by a Wilcoxon test, M = .88, SD = .18, W = 891, $p < .0001$). The same pattern was found for each Duration (see Table 7).

M2 explained 20.96 % proportion of the variation across our sample, (see adjusted R^2). It revealed a main effect of Age (χ^2 (2) = 8.320, p = .016). Post-hoc Tukey comparisons revealed that 6 – 7-year olds' performance (M = .78, SD = .23) were significantly lower than 8 – 9-year olds' (M = .93, SD = .11, p = .049) and 10 – 11-year olds’ performance (M = .93, SD = .11, p = .043). There was also a main effect of Duration (χ^2 (2) = 6.767, p = .034). A posteriori Tukey tests revealed that children performance were significantly better for LongE_DistantC-LongC questions (M = .95, SD = .15) than for LongE_RecentC-LongC (M = .84, SD = .28, p = .033) and ShortE_RecentC-DistantC questions (M = .85, SD = .30, p = .052). See Table 14 for the mean performance by age and

Table 7

Duration	Mean	SD
ShortE_RecentC-DistantC	.85***	.30
LongE_DistantC-LongC	.95***	.15
LongE_RecentC-LongC	.84***	.28
Total	.88***	.18

Note. * for p < 0.01; ** for p < 0.001; *** for p < 0.0001. Test reported in the Table are Wilcoxon tests to examine whether children's scores were above chance level. *p*-values are corrected for multiple tests (significance level is at .01).

Table 8

Model		AIC	Deviance	*p*-value
M0	1	185.72	181.72	
M1	+ Duration	180.94	172.94	=.012
M2	**+ Duration + Age**	**176.63**	**164.63**	**=.016**
M3	+ Duration * Age	181.59	161.59	=.551

condition.

3.2.1. Justification analysis

We analyzed children's justifications (n = 258) to have a clearer picture of children's conceptual understanding of the time course of food processes. We used the same four categories of justifications as in Experiment 1 (see Table 4). 3.87 % of children's justifications could not be coded as such and were not considered further. It is expected that a deeper understanding of the time course of food effects should result in more T + explanations. Two independent judges coded the justifications. The second judge coded 50 % of the justifications (n = 129). A Cohen's Kappa coefficient indicated that the agreement score between the judges was .85 which is considered to be "very good".

A chi-square test of independence was performed to examine the relation between Types of justification and Age, for each type of duration separately. For LongE_RecentC-LongC questions, it showed that the relation between these variables was significant, χ^2 (6) = 28.21, $p < .001$. Post-hoc Chi-square showed that for both 8 – 9-year olds and 10 – 11-year olds distribution compared to 6 – 7-year olds, age and type of justifications were related. 6 – 7-year olds significantly differed from 8 – 9-year olds (χ^2 (3) = 10.30, p = .016) and from 10 – 11-year olds (χ^2 (3) = 26.58, $p < .001$). Table 9 suggests that this is due to a larger number of T + in 10 – 11-year olds and 8 – 9-year olds than in 6 – 7-year olds who tended to refer more often to quantity (QN) and quality (QL). Note that the 8 – 9-year olds fell in between the other two groups with a high proportion of T + but also an intermediate percentage of QN and QL. For ShortE_RecentC-DistantC questions, χ^2 (6) = 13.58, p = .035, only 10 – 11-year olds differed significantly from 6 – 7-year olds (χ^2 (3) = 6.89, p = .032) in the distribution of justification types. As shown by Table 9, this seems to be due to the lower number of T + and the larger number of references to quantity (QN) in the younger group. The relation between Types of justification and Age was not significant for LongE_DistantC-LongC questions, χ^2 (6) = 5.97, p = .426.

3.2.2. Discussion

Our three age groups were quite efficient in the three conditions. The 6 – 7-year olds differed significantly from the two other age groups, and their performance in the long-term effect with a distant cause or a long-term cause condition were significantly lower than for the long-term effect with a recent cause or a long-term cause condition, which was virtually perfect in the three age groups. Taken together, these results show that long-term effects were more difficult when younger children had to distinguish short-term causes from long-term causes . As their justifications suggest, they seem to be confused by this situation since they allude to both the quantity and the quality of foods to justify their answers. When they refer to time, younger children refer more often to incorrect time parameters. In the other conditions, when the younger children's justifications differed from the two other age groups, they tended to

Table 9

Percentage of each justification categories by Age and temporal duration

Duration	ShortE_RecentC-DistantC				LongE_DistantC-LongC				LongE_RecentC-LongC			
Justification	T+	T-	QL	QN	T+	T-	QL	QN	T+	T-	QL	QN
6 – 7-year olds	70.8	8.3	0.0	20.9	48.3	6.9	13.8	31.0	20.7	17.2	24.2	37.9
8 – 9-year olds	92.0	0.0	4.0	4.0	69.2	11.5	3.8	15.5	61.5	11.5	15.5	11.5
10 – 11-year olds	90.0	10.0	0.0	0.0	66.7	6.7	3.3	23.3	86.2	0.0	10.4	3.4

Note: ShortE stands for "short-term effect", LongE stands for "long-term effect", RecentC stands for "recent short-term cause", DistantC stands for "distant short-term cause", and LongC stands for "long-term cause".

Table 10

The three categories of items used in Experiment 2B

ShortC_RecentE-DistantE	Pierre ate a big cake when he was young: ● Did his tummy hurt after he ate the cake OR ● Does his tummy hurt today because of the cake? Pierre ate a big plate of fries when he was young: ● Did his tummy hurt right after having eaten the fries OR ● Did his tummy hurt for several days after having eaten the fries?
ShortC_LongE[Yes]-LongE[No]	Arthur ate a big lunch with fatty foods yesterday, what is it going to happen? ● He is more overweight today than yesterday OR ● He is the same as yesterday, he does not change. Louis ate a big steak yesterday, what is it going to happen? ● He has become stronger today OR ● He is as strong today as yesterday, he does not change.
LongC_LongE[Before]-LongE[Now]	Lucas ate a lot of fruits when he was young, but for some time he does not eat fruit anymore: ● Did Lucas have energy when he was young OR ● Does Lucas have energy, now? Lola drank a lot of good milk when she was young, but for a long time she does not drink it anymore: ● Was Lola healthier when she was drinking OR ● Is Lola healthier now?

Note. ShortC stands for “short-term cause”, LongC stands for “long-term cause”, LongE[Before] stands for “long-term effect at that time”, LongE [Now] stands for “long-term effect of now”, RecentE stands for “recent short-term effect” and DistantE stands for “distant short-term effect”. LongE [Yes] stands for long-term effect yes, LongE[No] stands for long-term effect no.

refer to the quantity of food to justify their choice.

4. Experiment 2B: which effect for a cause?

Experiment 2A compared two causes for a given effect. In Experiment 2B, we did the reverse and considered the effects of a given cause. For example, what would be the effect of eating a lot yesterday, either being overweight or being the same today than yesterday. Again, we distinguished short- and long-term causes and effects, which gave rise to three types of cases (see materials). We were interested in children’s ability to understand long-term causes and their duration, and by short-term causes and their long-term effects (if any) or the time-course of these short-term causes.

4.1. Methods

4.1.1. Participants

Participants were the same as in Experiment 2A.

4.1.2. Materials

We constructed three types of statements. First, a long-term cause (LongC) (e.g., eating fruits on a regular basis, for a long time) has either long-term effects at the time the character ate it or now even though this character does not eat it for quite some time (LongC_LongE[Before]-LongE[Now]). Second, a short-term cause (e.g., eating a big cake once when the character was a child) had an immediate effect (e.g., a belly pain right after the character ate the food) or later (e.g., today) (ShortC_RecentE-DistantE). Third, a short-term cause (e.g., eating a big meal yesterday) will elicit long-term effect or not (e.g., being more overweight today or not) (ShortC_LongE[Yes]-LongE[No]), (see Table 10).

As in Experiment 2A, we used drawings to explain what was meant by a long time ago or recently, so that children could understand when and for how long the depicted events took place. We also used pictures of characters to provide a more realistic context for the task.

4.1.3. Procedure

The procedure was the same as in Experiment 2A. This experiment always took place after Experiment 2A.

4.2. Results

As in Experiment 2A, The predictive variables were Age (6 − 7-year olds, 8 − 9-year olds and 10 − 11-year olds), and Duration (ShortC_RecentE-DistantE, ShortC_LongE[Yes]-LongE[No], LongC_LongE[Before]-LongE[Now]). The interaction between Age and Duration was not selected because the model with this interaction (model M3, see Table 12) did not better fit the data than the model without the interaction (model M2, see Table 12).

Overall, children were above chance level (as attested by a Wilcoxon test, M = .67, *SD* = .20, W = 560, $p < .0001$, see Table 11). The same pattern was found for each Duration, excepted for ShortC_RecentE-DistantE (see Table 11).

M2 explained 38.99 % proportion of the variation across our sample, as demonstrated by the adjusted R^2. It revealed a main effect

Table 11

Duration	Mean	SD
ShortC_RecentE-DistantE	.37	.35
ShortC_LongE[Yes]-LongE[No]	.72***	.27
LongC_LongE[Before]-LongE[Now]	.91***	.27
Total	.67***	.20

Note. * for p < 0.01; ** for p < 0.001; *** for p < 0.0001. Tests reported in the Table are Wilcoxon tests to examine whether children' scores were above chance level. *p*-values are corrected for multiple tests (significance level is at .01).

Table 12

Model		AIC	Deviance	*p*-value
M0	1	332.44	328.44	
M1	+ Duration	274.70	266.0	< .001
M2	**+ Duration + Age**	**259.78**	**247.78**	< **.001**
M3	+ Duration * Age	262.07	242.07	=.222

of Age (χ^2 (2) = 18.664, p < .001). Post-hoc Tukey comparisons revealed that 6−7-year olds performance (M = .52, SD = .20) were significantly lower than 8−9-year olds (M = .68, SD = .13, p = .045) and 10−11-year olds' (M = .80, SD = .14, p < .001). There was also a main effect of Duration (χ^2 (2) = 48.807, p < .001), children's performance were significantly better for LongC_LongE [Before]-LongE[Now] questions (M = .91, SD = .27) than for ShortC_RecentE-DistantE (M = .72, SD = .27, p = .005) and than for ShortC_LongE[Yes]-LongE[No] (M = .37, SD = .35, p < .001). Also, they performed significantly better for ShortC_RecentE-DistantE than for ShortC_LongE[Yes]-LongE[No] questions (p < .001). See Table 14 for percentage correct by age and condition.

4.2.1. *Justifications analysis*

As shown in Table 13, the same categories were used to analyze children's justifications (n = 258). 7.5 % of children's justifications could not be coded as such and will not be considered further. Two independent judges coded the justifications. The second judge coded 50 % of the set of justifications (n = 129). A Cohen's Kappa coefficient showed that the agreement score between the judges was .84 which is "very good" according to Altman (1990).

Again, we were interested in the distribution of the four justification types between age groups in each of the temporal duration categories taken separately. For ShortC_RecentE-DistantE, a chi-square test revealed that the three age groups did not give the same justifications, χ^2 (6) = 14.42, p = .025. Post-hoc chi-squares revealed a significant difference between 10−11-year olds and 6−7-year olds. As shown by Table 13, older children referred more to time (T+) and less to quantity (QN) than 6−7-year olds (χ^2 (3) = 11.26, p = .010). For ShortC_LongE[Yes]-LongE[No] (χ^2 (6) = 16.51, p = .011), this was also the case (χ^2 (3) = 15.37, p = .002). The relation between Types of justification and Age was not significant for LongC_LongE[Before]-LongE[Now] questions, χ^2 (6) = 2.68, p = .848.

4.2.2. *Discussion*

This experiment sought to establish whether children would derive effects from a given cause. There were age differences but also significant differences between the temporal duration conditions. Again the long-term cause with past or present long-term effect options condition was easier than the other two conditions suggesting that most children understand these long-term processes. However, there was a high percentage of reference to the quality of foods and, to a lesser extent, of incorrect temporal justifications (in younger children) which underlines their difficulties with long-term influences. Children had more difficulties in the condition in which a long-term consequence of a short-term cause should be denied (people don't get more overweight overnight). Both 6−7-year olds and 8−9-year olds gave few correct references to time justifications and referred more to food qualities.

5. General discussion

Two experiments studied the development of children's understanding of time-based causes and effects of foods, contrasting

Table 13

Percentage of each justification categories by Age and temporal duration

Duration	ShortC_RecentE-DistantE				ShortC_LongE[Yes]-LongE[No]				LongC_LongE[Before]-LongE[Now]			
Justification	T+	T-	QL	QN	T+	T-	QL	QN	T+	T-	QL	QN
6−7-year olds	55.6	3.7	7.4	33.3	7.1	7.1	60.8	25.0	48.0	20.0	24.0	8.0
8−9-year olds	70.9	8.3	0.0	20.8	25.0	12.5	50.0	12.5	58.3	16.7	20.8	4.2
10−11-year olds	93.3	0.0	0.0	6.7	51.8	10.3	31.0	6.9	58.6	6.9	27.6	6.9

Table 14

Percentage of correct responses for each experiment by Age and temporal duration

Experiment	Experiment 1			Experiment 2A			Experiment 2B		
Duration	ShortE_ShortC	LongE_ShortC	LongE_LongC	ShortE_RecentC-DistantC	LongE_DistantC-LongC	LongE_RecentC-LongC	ShortC_RecentE-DistantE	ShortC_LongE[Yes]-LongE[No]	LongC_LongE[Before]-LongE[Now]
6 – 7-year olds	.48	.44	.98	.70	.90	.73	.60	.20	.77
8 – 9-year olds	.72	.83	.85	.96	.96	.89	.77	.31	.96
10 – 11-year olds	.84	.87	.87	.90	1	.90	.80	.60	1

short-term and long-term effects and causes. To the best of our knowledge, our experiments are the first to address this issue and to reveal clear dissociations between short- and long-term effects of foods in children.

As hypothesized, all the experiments revealed a developmental progression. However, different developmental patterns were found across conditions. Conditions involving long-term causes and effects gave the highest level of performance in the two experiments when long-term effects and causes were combined. In contrast, with short-term effects and/or causes, (as the condition ShortE-ShortC in Experiment 1, ShortE_RecentC-DistantC in Experiment 2A, and ShortC_LongE[Yes]-LongE[No]Experiment 2B), the younger age group and sometimes even the ten-year-olds encountered difficulties. Last, reasoning on the effects of causes (2B) was difficult for younger children especially when they had to decide whether a short-term cause would have a long-term effect or not. In this respect, condition ShortC_LongE[Yes]-LongE[No] in experiment 2B had a mean of 37 % of correct answers whereas the worse condition in 2A (LongE_RecentC-LongC) reached 84 %.

In most cases, older children justified their answers in terms of time (T+) more often than younger children who justified their answers either in terms of food quality or quantity. The pattern of results did not confirm our hypothesis that children's results would be higher for short-term trials. Indeed, we expected that the short-term effects of foods (e.g., indigestion) would be easier to understand than long-term effects because the relationship between ingestion and effect is immediate or at least very close to the triggering event. In fact, we observed the opposite pattern. Children's justifications, especially in the case of younger children for the most difficult conditions, show that they reasoned in terms of food healthiness. This might be due to the fact that adults, most of the time, refer to foods in terms of their healthy or unhealthy qualities, or quantities, with no reference to any temporal dimensions.

Our study adds important information to previous studies such as the one by Wellman and Johnson (1982) that showed that younger children misunderstand the consequences of different types of diets on weight, health, energy, height and strength. Children also mentioned diets as the main justification for the differences, referring to quantity or quality of foods (see Table 1, p. 140) depending on the dimension (i.e., food quantity for fat and quality for health). They extended the role of foods to height, regardless of the type of food. Our data add a duration component to this picture, showing that, when explicitly asked to choose between time-related options, even younger children understood the time-scale of a particular diet or food intake and justified it in terms of time. However, children struggled more with short-term phenomena that they considered being of the same nature as long-term effects or causes and referred more often to quantity or quality of foods to justify their answers. This speaks, again, in favor of an understanding that would be biased towards salient dimensions of foods such as quantity or quality. Children's explanations were more often based on quantity when the cause was short-term, and on quality when the cause or the effect was long-term. This suggests they begin to understand that short-term phenomena might be due to the quantity of food whereas long-term phenomena are correlated with their quality. This is speculative, however, and should be investigated in future studies. In any case, our data cannot be explained by a lack of knowledge regarding healthy and unhealthy foods. Indeed Nguyen (2008) showed that four-year-olds inductions of novel properties were driven by the distinction between healthy and unhealthy food categories.

Regarding the difficulty of ShortE_ShortC statements, as mentioned above, they might result from the difficulty to define what short-term effects mean in the case of food. When does a short-term cause begin or stop its effects is, to some extent, a matter of appreciation and probably requires more precise knowledge than for long-term causes that are supposed to have enduring effects. Moreover, since foods have occasionally short-term effects (e.g., indigestion), younger children might be tempted to generalize these effects to any short-term case, when they do not know what the underlying physiological mechanisms are. In a similar way, Teixeira (2000) showed, in the context of digestion, that some younger children justified the trajectory of foods in terms of gravity (e.g., "after they reach the stomach, they fall down in the feet and the legs"). This makes sense if children do not know that the notion of a cavity, such as the stomach, does not extend to the entire body and if children are unaware of the digestion mechanisms. In fact, even though gravity is a precise explanatory mechanism, it does not fit with a digestion context.

When compared to inductive studies, our experiments show that children were correct at older ages than in previous research showing that four-year-olds can sort foods into healthy and junky foods and reason on this basis (2008, Nguyen, 2007). The main difference with our research is that in these former experiments participants did not have to reason about underlying causes of biological properties, but to extend properties to other categories. When four-year-old participants, in Nguyen and Murphy (2003), had to extend a biochemical property in a forced-choice inductive inference task, they chose the taxonomically related food less than chance (e.g., "bread has pary in it"), whereas 7-year-olds and adults made the correct taxonomic choices. Maybe it is possible to draw an analogy between our experiments and Nguyen and Murphy's results. In Nguyen and Murphy (2003), the induction task was succeeded by older children because it requested to infer biological unknown properties, which is analogous to the biological complex mechanisms that were considered in the present experiments. However, we expect better results for property-based induction tasks than for tasks that require to reason on explicit time-based properties or general explanatory biological mechanisms, especially when there is a competition between explanatory properties such as time, quantity, and quality for a given expected food effect.

5.1. General explanatory processes and physiological mechanisms

Inagaki and Hatano (2002); Morris et al. (2000) referred to vitalism as an explanatory construct in children's reasoning about foods (but also in adults). Can children and even adults use other explanatory more specified mechanisms? We contend that time-based, quality- and quantity-based explanatory mechanisms stand in between vitalism and scientifically-based, physiological explanations. "Providing energy" is the least specified explanatory mechanism for food action. Quantity and quality of the food are a step further because these two dimensions of food are a differentiation among food-related mechanisms while satisfying the energy goal. The difference between these mechanisms is acknowledged by participants in Wellman and Johnson (1982) who referred more to quantity or quality depending on the tested effect of food. Adding the time factor accounts for differences in the effects of quantities and qualities of foods (e.g., inappropriate foods or too much of a food can cause indigestion in a short time, or a healthy food should be consumed on a regular basis). Adding factors in the explanation of food effects such as time also means introducing new interactions between these factors which increases the complexity of the explanation. Despite the fact that children's explanations are not physiological explanations, it is reasonable to hypothesize that these explanations are also the only ones that are available for the layperson. In this respect, adults differ from younger kids in the way they successfully combine a set of core explanatory dimensions such as the ones we underline here. However, for most of them, they are probably available early in development even though younger kids have difficulties in combining them.

5.2. Education perspectives

Most of the food-related messages targeted at children and adults emphasize their nutritional (often via their sensory, e.g., fatty, sweet) qualities. In terms of the above mechanisms, it means hiding the importance of other interacting mechanisms and contributes to reifying the corresponding qualities as the most important ones. One downside of this approach is that children (mis)understand foods in absolute terms as being good or bad. The above data and others suggest that even young children can understand more complex dimensions than expected, even though not completely (see also Gripshover & Markman, 2013, showing that food education programs that refer to the components of foods can contribute to changes in food consumption). Food education should address these supposedly more complex dimensions before repetitions of far too simple messages that overemphasize some explanatory dimensions at the expense of other ones.

5.3. Limitations and future directions

One limitation of the present study is the fairly low number of statements illustrating each condition. Increasing the number of statements and more systematically introducing different types of contexts in which time-related factors might interact with food-related mechanisms is important if we want to better understand whether children's understanding of time-related processes is general or follow different developmental progressions in different time contexts. Another limitation is that the present study does not tell us which underlying time-based explanations children possess and how they might interact with the notion of quality of food (for example). Last, it would be interesting to investigate children's intuitions regarding specific categories of foods and, further, the role of some of their components. Indeed, educational contents targeted at children often refer to the role of food components and what is really understood by children, especially younger children, deserves to be further investigated.

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