FEEDING THE MIND:
the development of food categories and its association with food neophobia and pickiness in young children

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SUMMARY

Food neophobia and pickiness in young children are two strong psychological barriers to fruit and vegetable consumption. It is therefore essential to understand the mechanisms underpinning these two kinds of food rejections to promote the adoption of healthy eating behaviors among preschoolers.

In this context, the first objective of the thesis was to develop and validate a hetero-assessment scale to measure efficiently food neophobia and pickiness for French children as young as 2 years of age. The Child Food Rejection scale developed represents an efficient tool for studying food rejection dispositions in this young population.

The second objective was to clarify the concept of pickiness and to provide an insight into the relationship between food neophobia and pickiness. The results revealed that food neophobia and pickiness capture a same kind of fear for new and potentially toxic food.

The third objective was to directly investigate the relationship between food categorization development in young children and their food neophobia and pickiness. This investigation revealed negative connections between cognitive development and food rejection dispositions. Food acceptance probably depends on the maturity of the food categorization system.

Finally, the fourth objective was to design an intervention, exploiting the empirical evidence on the relationship between food categorization and food rejections, to positively influence children food rejections. The results add to the promising body of evidence that visual exposure is effective to decrease food rejection behaviors.

The thesis offers a contribution to the understanding of the development of food rejection during toddler and preschool ages and is one of the first studies to investigate directly the connection between food rejection dispositions and cognitive development. This contribution will be valuable to design interventions aiming at improving children eating habits.

Keywords: food neophobia; food pickiness; 2 to-6-year-old children; cognitive development; color information; questionnaire development; visual exposure.

RÉSUMÉ

La néophobie et la sélectivité alimentaire des jeunes enfants ont des conséquences préoccupantes sur la santé notamment parce qu'elles concernent principalement les fruits et les légumes. Il est donc essentiel de promouvoir l'adoption de comportements alimentaires sains chez le jeune enfant.

Dans ce contexte, le premier objectif de la thèse était de développer et de valider un questionnaire pour mesurer efficacement la néophobie et la sélectivité alimentaire chez les enfants français dès l'âge de 2 ans. Le questionnaire de rejets alimentaires pour enfant développé dans cette thèse est un outil efficace pour étudier les rejets chez cette population.

Le deuxième objectif était de mieux définir le concept de sélectivité alimentaire et d'étudier la relation entre néophobie et sélectivité alimentaire. Les résultats ont montré que la néophobie et la sélectivité alimentaire capturent un même type de peur pour les aliments nouveaux et potentiellement toxiques.

Le troisième objectif était d'étudier directement la relation entre le développement de la catégorisation des aliments chez les jeunes enfants et leur niveau de néophobie et sélectivité alimentaire. Les résultats ont montré des liens négatifs entre le développement cognitif et les rejets alimentaires. L'acceptation des aliments dépend probablement de la maturité du système de catégorisation alimentaire.

Enfin, le quatrième objectif était de concevoir une intervention, en exploitant les données empiriques sur la relation entre développement cognitif et rejets alimentaires, afin d'influencer positivement ces derniers chez les enfants. Les résultats sont prometteurs et montrent que l'exposition visuelle est efficace pour diminuer les comportements de rejets alimentaires.

La thèse offre une contribution à la compréhension des mécanismes sous-tendant la néophobie et la sélectivité alimentaire et est l'une des premières recherches à étudier directement le lien entre ces rejets et le développement cognitif. Cette contribution sera utile pour concevoir des interventions visant à améliorer les habitudes alimentaires des enfants.

Mots-clefs: Néophobie alimentaire; sélectivité alimentaire; enfants de 2-6 ans; développement cognitif; information de couleur; développement de questionnaire; exposition visuelle.

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GENERAL INTRODUCTION

Knowing what to eat is of central biological importance to humans. Unlike species that consume just one type of food, after weaning, children need to include new food resources to have a diverse diet, to ensure healthy development and survival. However, this search for variety is a highly risky endeavor, as new substances may be toxic, and a single incorrect choice in this search could easily lead to death. So which are the design features that have emerged through natural selection to solve this adaptive problem[1] (referred as the *omnivore dilemma*, Rozin, 1979)?

Food neophobia (defined as a reluctance to eat new foods; Pliner & Hobden, 1992) and ***food pickiness*** (defined as a restricted intake of new and familiar foods and a rejection of certain textures; Taylor, Wernimont, Northstone, & Emett, 2015), appearing in the first few years of life, are considered to be design features, overcoming the adaptive problem of food selection (Levene & Williams, 2017; Rozin, 1979). These two kinds of food rejection dispositions prevent individuals from ingesting substances that are potentially poisonous (Cashdan, 1994; Pliner, Pelchat, & Grasbski, 1993; Rozin, 1979).

The environment in which humans have evolved in was very different from our modern environment. Our ancestors spent most of our species' evolutionary history living in hunter-gatherer societies (Cosmides, Tooby & Barkow, 1992). Within a hunter-gatherer environment, foraged foods (e.g., fruits, vegetables), have been essential food sources, as well as potentially toxic substances (Ungar & Sponheimer, 2011). It is likely that the environment of our hunter-gatherer ancestors have shaped our minds in ways that continue to guide food selection. Accordingly, it has been reported that **food neophobia and pickiness are mainly targeting fruits and vegetables** (Dovey, Staples, Gibson, & Halford, 2008). Numerous studies have uncovered negative associations between food neophobia and pickiness and intake of fruits and vegetables (Fletcher, Wright, Jones, Parkinson & Adamson, 2017; Perry, Mallan, Koo, Mauch, Daniels & Magarey 2015).

Design features that exist because they solved problems efficiently in the past will not necessarily be adapted to our present environment, as the rate at which an organism adapts to its environment is slower than the rate of environmental change (a phenomenon referred as *adaptive lag*; Cosmides et al., 1992). In contrast to the hunter-gatherer environment, the

[1] An adaptive problem is a problem, whose solution can affect reproduction, and hence evolutionary success (Cosmides, Tooby, & Barkow, 1992).

contemporary food environment is full of highly processed foods (e.g., pasta, candies) that not only look different than natural foods but may also have different physical properties. For instance, most modern individuals require their wisdom teeth to be surgically removed as nearly all of our food is externally processed through chopping and cooking.
Accordingly, while food neophobia and pickiness probably had an adaptive value in hunter-gatherers' hostile food environment, in our modern societies, where food safety is controlled in food supply chains, they are maladaptive. As food rejection dispositions lead to a low consumption of fruits and vegetables by young children (Dovey et al., 2008), they are responsible for a reduction in dietary variety (Birch & Fisher, 1998; Falciglia, Couch, Gribble, Pabst, & Frank, 2000). This variety is needed for normal and healthy child development (Carruth, Skinner, Houck, Moran, Coletta, & Ott, 1998; Cashdan, 1998) and may protect against chronic diseases later in life, such as metabolic syndromes, diabetes, and cardiovascular diseases (Van Duyn & Pivonka, 2000).

The impact of food neophobia and pickiness extends well beyond childhood, since dietary habits acquired during childhood largely determine dietary patterns in adulthood. In a longitudinal study, Nicklaus, Boggio, Chabanet and Issanchou (2005) found that, the food repertoire in adolescence and early adult life was influenced by food exposure and food choice behaviors before the age of 4. This influence was even greater for vegetable products compared to animal products (Nicklaus et al., 2005). **It is therefore essential to understand the mechanisms underpinning food neophobia and pickiness to promote the adoption of healthy eating behaviors among preschoolers.**

As stated above, food rejections are considered to be a solution to the adaptive problem of food selection, however it is only one partial solution to the problem. The system responsible for the inclusion of previously unknown food exemplars in our diet has still to be identified. A very plausible candidate is our food categorization system allowing for a food/nonfood distinction and discrimination between different food items, which enables efficient sampling of new food resources and enrichment of the food repertoire. Categorization is a fundamental cognitive tool that allows us to organize objects into groups (Vauclair, 2004). Without such abilities, each item would be perceived as new, and it would be impossible to generalize its properties (such as assuming that because a carrot is edible, other carrots will be too; Murphy, 2002).

However little is known about whether categorization abilities in the food domain play a significant role in shaping young children's eating behaviors, particularly their reactions to new foods (Mura Paroche, Caton, Vereijken, Weenen & Houston-Price, 2017).

Within this context, the present PhD project is a joint initiative by the Institute Paul Bocuse Research Center (IBPR), the PSYCLE research center hosted at the Aix-Marseille-University (PSYCLE EA3273), and the foundation Daniel and Nina Carasso (FDNC), which financially supported the project. The theoretical aim of this PhD project started in November 2014, is to determine whether (and how) food categorization abilities play a significant role in shaping young children's food neophobia and pickiness. Its practical goal is to develop and test the effectiveness of interventions in school canteens, to promote the acceptability of rejected foods in young children.

The present thesis dissertation comprises eight chapters, articulated in four parts. It begins with a review of current literature relevant to food rejections among toddlers and preschoolers, and a presentation of the research hypotheses (Part A, chapters 1-4). The review is split into three chapters. First, a review of definitions, developmental trends and measurement tools of both neophobia and pickiness is provided (chapter 1). The second part of the review presents an overview of the factors involved in children' food rejections, with a focus on children' food categorization abilities (chapter 2). The review concludes with a summary outlining the strategies currently used to overcome food rejections (chapter 3). Part A ends with a presentation of the research hypotheses and the methodologies employed to test them (chapter 4).

Part B contains one chapter (chapter 5), presented as a paper written in journal format. This chapter presents the development and validation of a questionnaire, to assess food neophobia and pickiness, in French young children, a necessary preliminary phase of the present project.

Part C contains two chapters (chapter 6 and chapter 7) also presented as papers written in journal format. Chapter 6 presents an experimental study which examined categorization of foods in early childhood and how this may affect the level of a child's food rejection. Chapter 7 presents another experimental study which examined the relationship between food category-based induction development in young children and their food neophobia and pickiness.

Part D, contains one chapter (chapter 8) also presented as paper written in journal format. Chapter 8 presents our last experimental study: the development of an intervention, based on visual exposure, to positively influence children food rejection behaviors.

Finally, a general discussion gives an overview and discussion of the thesis as a whole, including a summary of the main findings and the contribution of the empirical chapters (5-8) to current understanding about young children food neophobia and pickiness.

PART A. LITERATURE REVIEW AND RESEARCH HYPOTHESES

Chapter 1. Food rejections: definitions, developmental trends and measurement

To induce behavioral changes in children's eating habits, it is critical to consider strategies that take into account the diversity of factors interacting with food acceptance: innate and rapidly acquired taste preferences (Rozin, 1979), cultural norms (Kannan, Carruth, & Skinner, 1999), etc. However, the two strongest psychological barriers to increase a child's dietary variety seem to be food neophobia (Pliner & Hobden, 1992) and pickiness (Birch, Johnson, Andresen, & Peters, & Shulte, 1991; Dovey, Staples, Gibson, & Halford, 2008). The first chapter of this thesis defines and presents the developmental trends and measure assessments of these two notions.

1. Food neophobia

1-1- Definition

Food neophobia is defined as the reluctance to eat, or the fear of, new foods (Pliner & Hobden, 1992). Neophobic reaction results in new foods being rejected on mere sight, even before being tasted (Cashdan, 1998; Dovey et al., 2008). A new food can be genuinely new (never encountered before, e.g., a durian fruit for most European people) or perceived as new (encountered before but no feeling of familiarity[2] is induced). Familiarity is thought to be a subjective feeling that occurs when processing of a stimulus is unconsciously attributed to past experiences (Wagner & Gabrieli, 1998). The concept of familiarity in its general sense then refers to the cognitive ability to apply the knowledge gained through experiences with objects or stimuli (Aldrige, Dovey, & Halford, 2009).

Some authors agree that food neophobia can be considered as a true phobia. It has been shown that food neophobia is associated with typical physiological fear responses, such as galvanic skin response and an increase in pulse or respiration rhythm (Raudenbush & Capiola, 2012). Additionally, food neophobia in infancy is often associated with an increased anxiety (Galloway, Lee & Birch, 2003) or even disgust over new foods (Brown & Harris, 2012; Martins & Pliner, 2006), as well as with attentional biases toward new foods (Maratos & Staples, 2015). All three components (anxiety, disgust, or attentional biases) are often found in phobias. For example, a

[2] The term "feeling" here refers to an epistemic feeling which is a particular kind of experience that one undergoes when confronted with cognitive tasks (e.g., the feeling of knowing, the tip-of-the-tongue phenomenon etc...; Arango-Muñoz, 2014).

person who is phobic of snakes, will find them more disgusting, and will direct his/her attention more readily toward a picture of it, than a person who is not (Cisler & Köster, 2010).

Food neophobia is often conceptualized as a *personality trait*, a continuum along which children can be located in terms of their stable and persistent propensity to avoid new foods (Dovey et al., 2008; Pliner & Hobden 1992). Indeed, as listed below, food neophobia exhibits most of the characteristics known as supporting the definition of a personality trait (Zentner & Bates, 2008):

(a) *Heritability*. Using a twin study, comparing intra-class correlations between monozygotic twins (sharing all their genes) and dizygotic twins (sharing on average half their genes), Cooke, Haworth, and Wardle (2007) found that food neophobia is highly heritable. The authors found that genetic influences account for 78% of the variance in neophobia.

(b) *Linked to biological mechanisms (e.g., neurochemical, neuroanatomical).* A handful of studies are addressing the potential implication of neural mechanisms in food neophobia. Promising results show that innate anxiety and neophobia are both subjected to visceral modulation, through abdominal vagal afferents, possibly via changing limbic neurotransmitter systems (Klarer, Arnold, Günther, Winter, Langhans, & Meyer, 2014).

(c) *Early ontogenetic appearance*. Food neophobia appear in the first few years of life and is fully expressed by preschool age (Dovey et al., 2008; Lafraire, Rioux, Giboreau & Picard, 2016).

(d) *Counterparts exist in primates as well as in certain social mammals*. Neophobic behaviors are commonly observed among omnivorous species, such as capuchin monkeys (Visalberghi & Addessi, 2000) or rats (Galef, 1993).

(e) *Generation of important individual differences.* Developing a scale to assess food neophobia as a trait, Pliner and Hobden (1992) found that people could be placed anywhere on the neophobic-neophilic continuum.

Nevertheless, food neophobia does not seem to exhibit one important characteristic of a personality trait: to be relatively enduring and predictive of conceptually coherent outcomes (Zentner & Bates, 2008). Indeed, while neophobia is thought to be relatively stable during early childhood (Addessi, Galloway, Visalberghi, & Birch, 2005), most researchers agree that, in late childhood, the expression of food neophobia importantly decreases (Dovey et al., 2008). Additionally, food neophobia is only partially predictive of coherent behavioral outcomes, since most studies found only medium correlations between neophobia and willingness to try new foods. A recent review of instruments developed to measure food neophobia (Damsbo-Svendsen, Frøst, & Olsen, 2017) revealed that the highest correlation between neophobia and willingness to try new foods found in the literature was 0.47 (Rubio, Rigal, Boireau-Ducept, Mallet, & Meyer, 2008). The lowest correlation was 0.11 (Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001).

This led some authors to rather address neophobia as a *state* (Rigal Frelut, Monneuse, Hladik, Simmen, & Pasquet, 2006), a transitory negative emotion (in the case of neophobia, fear), elicited by the idea of ingesting a specific food, in a specific context. In this view, the expression of food neophobia can be unstable, age-dependent, and modulated by context modalities such as food properties (Brown & Harris, 2012), individual's arousal (Pliner & Loewen, 2002), or social modeling (Laureati, Bergamaschi, & Pagliarini, 2014). This would possibly explain the partial prediction of behavioral outcomes. However, in the case of neophobia as a state, to say that a child is neophobic is just to say that the appropriate response (food rejection) will follow upon the appropriate stimulus (a new food), which is not an explanation of the mechanism responsible for the elicited fear.

To reconcile the distinction between food neophobia as a trait or as a state the concept of *disposition* is enlightening (Choi, 2012; Mumford, 1998). Dispositions are seen as genuine and functional properties ascribed to objects, kind or persons (e.g., the disposition *fragile* for a glass). To each dispositional property corresponds a typical manifestation (e.g., *shatter when struck* for a fragile glass), explained by a physical state or mechanism (possibly unknown). Importantly, to possess a disposition is not to be in a particular state, but to be liable to be in a particular state when certain circumstances are met (e.g., *if* the fragile glass is struck, it shatters). Neophobia could then be viewed as a disposition. Only when neophobic children are presented with new foods, they will present rejection behaviors. The circumstances are met when a food is genuinely new or perceived as new (i.e., encountered before but no feeling of familiarity is induced). As children develop and get older, fewer things are new for them, thus the circumstances that trigger food rejection behaviors occur more and more seldom, explaining the non-stability of neophobia during the lifespan.

This disposition is assumed to serve a protective function in potentially hostile food environments (Goldstein & Gigerenzer, 1999; Rozin, 1979). Humans need to have a diverse diet to ensure their nutritional health and survival. To satisfy this diversity, they must continually sample new food resources. However, this search for variety can prove hazardous, as new substances may be toxic, and a single mistake in this search could potentially lead to death. From the *omnivore's dilemma* perspective, Rozin (1979) described food neophobia as an efficient adaptive strategy for children to avoid the risk of ingesting new (and thus potentially poisonous) items, once they are mobile enough to reach for, and consume objects available in their proximal environment.

1-2- Developmental trend and gender differences

Neophobic behaviors appear at around 2 years of age, when children become mobile and could find themselves outside parental guidance (Cashdan, 1994; Dovey et al. 2008). There is however a contention in the literature as to whether neophobic behaviors increase progressively thereafter (Birch, McPhee, Soba, Pirok, & Steinberg, 1987; Cashdan, 1994; Harper & Sanders, 1975), or remain stable during early childhood (Addessi et al., 2005; Cooke, Wardle, & Gibson, 2003; Koivisto & Sjöden, 1996). On the one hand, authors as Harper and Sanders (1975) found that 5-year-old children tend to be more neophobic than their younger counterparts. On the other hand, Cooke and colleagues (2003) did not find any correlation between food neophobia and age within the 2-to 6-year-old age range.

Nevertheless, most researchers agree that in late childhood/beginning of adolescence, the expression of food neophobia decreases, until it reaches a relatively stable expression in adulthood (Dovey et al., 2008; Koivisto-Hursti & Sjöden, 1997; McFarlane & Pliner, 1997). Actually, the mere fact that fewer things are new for an adult or an adolescent, than for a child, automatically reduces the expression of food neophobia (Cooke & Wardle, 2005).

Concerning potential gender differences, most studies investigating food neophobia during childhood did not find gender differences (Birch et al., 1987; Cooke et al., 2003; Loewen & Pliner, 2000; Nicklaus, Boggio, Chabanet, & Issanchou, 2005). However, some studies have found differences (see Frank & Van Der Klaauw, 1994 for girls being more neophobic than boys; see Rigal, Chabanet, Issanchou, & Monnery-Patris, 2012 for boys being more neophobic than girls).

Therefore, there is a need for further research into gender and age effects, to be sure of the magnitude of the gender effect, if any, to search for potential mediating variables, and to better understand the nature of neophobia developmental path.

1-3- Measurement

1-3-1-Questionnaires

Methodologically speaking, it appears that when neophobia is conceptualized as a trait, scales are used (personality traits have been traditionally measured via scales; Zentner & Bates, 2008). The first researchers to develop a food neophobia scale were Pliner and Hobden (1992), who designed the Food Neophobia Scale (FNS). This questionnaire asks adult participants to indicate the extent to which they agree, or not, with statements about consumption of new foods, such as "If I don't know what is in a food, I won't try it" (see Fig. 1).
Originally devised to score adults' neophobia, the FNS was adapted to measure children's neophobia (Children Food Neophobia Scale, CFNS; Pliner, 1994).

Figure 1: Items of the Food Neophobia Scale (retrieved from Pliner, 1994).

Questions on adult version of the Food Neophobia Scale
I am constantly sampling new and different foods.
I don't trust new foods.
If I don't know what is in a food, I won't try it.
I like foods from different countries.
Ethnic food looks too weird to eat.
At dinner parties, I will try a new food.
I am afraid to eat things I have never had before.
I am very particular about the foods I will eat.
I will eat almost anything.
I like to try new ethnic restaurants.

Both Pliner's scales have been widely used to measure food neophobia. The scales have been successfully adapted (e.g., the Fruits and Vegetables Neophobia Instrument, FVNI, Hollar, Paxton-Aiken, & Fleming, 2013; the Food Neophobia Test Tool, FNTT, Damsbo-Svendsen et al., 2017; the Questionnaire pour Enfant de Neophobie Alimentaire, QENA, Rubio et al., 2008). The scales have also been translated into several languages, including French (Adapted Food Neophobia Scale, AFNS; Reverdy, Chesnel, Schlich, Köster, & Lange, 2008), Spanish (Spanish version of the Food Neophobia Scale, SFNS; Fernandez-Ruiz, Claret, & Chaya, 2013), or Italian (Italian Children Food Neophobia Scale, ICFNS; Laureati, Bergamaschi, & Pagliarini, 2015).

Nowadays, the majority of research on food neophobia focuses on neophobia expressed in childhood. Then both auto-assessment scales (i.e., children respond for themselves) and hetero-assessment scales (i.e., caregivers respond for their children) are used (hetero-assessment scales are commonly used with children younger than 5-to 6-year-old). It is important to have in mind that hetero-assessment scales give only approximation of children own food behaviors. There are potential social desirability biases (i.e., parents may present a better image of their children or themselves), or parents may sometimes project their own behaviors onto those of their children (Mata, Scheibehenne, & Todd, 2008). In fact, caregivers' reports of their children's neophobia only moderately correlate with children's report of their own neophobia (e.g., r = 0.3 in Pliner, 1994).

In a recent review of methods used to assess preschool children's eating behaviors, De Lauzon-Guillain and colleagues (2012) pointed out that most of existing scales measuring children's food neophobia are not entirely psychometrically sound. Indeed, only the QENA (Rubio et al., 2008) achieved all validity and reliability criteria. Other questionnaires, such as the widely used FNS/CFNS, failed to validate construct validity and/or temporal reliability. Using a confirmatory factor analysis, Ritchey, Frank, Hursti and Tuorila (2003) found that the FNS was not unidimensional and did not measure solely food neophobia. Therefore, there is a need for further development of tools to measure more rigorously food neophobia, and to be able to properly compare children across studies or cultures.

1-3-2-Behavioral tasks

As previously mentioned, neophobia is also conceptualized as a state, a transitory negative emotion that can be triggered in some contexts and that fluctuates in time. It appears that when the focus is on state neophobia, behavioral food tasks are used (instead of scales; Rigal et al., 2006). The most common behavioral task used to assess neophobia is the "Willingness to Try New Food" task (WTNF), in which children are presented with new foods and are asked to try them. The actual presence of food is believed to trigger an emotional response (McFarlane & Pliner, 1997; Pelchat & Pliner, 1995; Pliner & Loewen, 2002).

The first WTNF task was developed by Pliner and Hobden (1992). It consists for participants to rank in order six *a priori* new foods from five categories (salads, dips, crackers, vegetables and snacks) in terms of their willingness to taste them (in a fictitious subsequent tasting session). Pliner and Hobden's food task has been widely used as a measure of state neophobia and largely adapted. Some authors used pictures of foods instead of actual foods (Rubio et al., 2008), while other used real foods (Laureati et al., 2015). Some authors added familiar foods to the task, and compared the number of familiar foods tasted to the number of new foods tasted (Laureati et al., 2015). Further, in some WTNF, children had to taste the foods (Pliner, 1994), while on the original task, they just had to indicate which foods they were willing to taste (Pliner & Hobden, 1992). It should be noted that usually, the willingness to try new foods is moderately to highly correlated to scores on food neophobia scales (Rubio et al., 2008; Laureati et al., 2015; Pliner, 1994 for $0.3 < r < 0.5$).

2. Food pickiness

2-1- Definition

Food pickiness is defined as the rejection of a substantial number of foods that are new, but also can be familiar and previously accepted foods (Birch et al., 1991; Taylor, Wernimont, Northstone, & Emett, 2015). Food pickiness can also be considered as the rejection of certain food textures (Smith, Roux, Naidoo, & Venter, 2005). A major difference between food neophobia and food pickiness is the point of rejection of the food itself. With pickiness, rejection does not occur only on mere sight but can occur after the tasting step. In this case, the food is tasted but not swallowed. Finally, pickiness in infancy is often associated with an increased anxiety over food (Farrow & Coulthard, 2012; Galloway et al., 2003) or with greater sensitivity to sensory information such as tactile information (Farrow & Coulthard, 2012; Nederkoon, Jansen, & Havermans, 2015).

Contrary to food neophobia, there is to date no single widely accepted definition of food pickiness, although most definitions include an element of restricted intake of familiar foods. Researchers agree that much research is needed to fully understand and define this phenomenon (Cole, An, Lee, & Donovan, 2017; Taylor et al., 2015). This is further complicated by the use of a variety of terminology, including picky eating, fussy eating, choosy eating and faddy eating.

To our knowledge, food pickiness has not been conceptualized either as a trait or as a state, and is more often perceived as a form of eating disorder. Indeed, in the most recent version of the Diagnostic and Statistical Manual of Mental Disorders (DMS-V), strong forms of pickiness are diagnostic criteria for Avoidant/Restrictive Food Intake Disorder (ARFID). Nevertheless, and as listed below, it appears that, food pickiness exhibits several of the characteristics supporting the definition of a personality trait (Zentner & Bates, 2008).

(a) *Heritablylity*. Using a twin procedure, Smith, Fildes, Cooke, Herle, Shakeshaft, Plomin and Llewellyn (2016) found that variation in food pickiness is for a non-negligible part explained by genetic factors. The authors found that genetic influences account for 46% of the variance in pickiness.

(b) *Linked to biological mechanisms.* A greater sensitivity to sensory information (Farrow & Coulthard, 2012) could potentially explain the rejection of certain textures.

(c) *Early ontogenetic appearance*. Pickiness appears in the first few years of life and is fully expressed by preschool age (Dovey et al., 2008; Lafraire et al., 2016).

(d) *Generation important individual differences:* Such differences are shown with pickiness scales (the Children's Eating Behavior Questionnaire, CEBQ; Wardle, Guthrie, Sanderson, & Rapoport, 2001).

However, because food pickiness is not stable across the life span, it also arguable that food pickiness could be just a state, a transitory negative emotion, such as disgust, elicited by the idea of ingesting a specific texture, in a specific context, that could be modulated by different modalities, such as pressure to eat (Antoniou, Roefs, Kremers, Jansen, Gubbels, Sleddens, & Thijs, 2015). Thus, similarly to food neophobia, arguing that food pickiness is a disposition could resolve both failure of trait (non-stability across the life span) and state food pickiness (absence of an explanation of the mechanism responsible for the elicited emotion).

2-2- Developmental trend and gender differences

Food pickiness is a very common behavior in young children with an average of 50 % of children judged to be picky by their caregivers between 19 and 24 months of age (Carruth, Ziegler, Gordon & Barr, 2004). As true for food neophobia, food pickiness is an age-related phenomenon and is believed to be temporary (Dovey et al., 2008). However, a contention in the literature exists concerning the developmental path of food pickiness. According to some authors (Dubois, Farmer, Girard, Peterson & Tatone-Tokuda, 2007) the prevalence of pickiness remains relatively stable during early childhood (2.5-to 4.5-year-old). On the other hand, a recent longitudinal study by Mascola, Bryson, and Agras (2010) showed that the highest incidence of pickiness occurs in early childhood (at around 2 years), and subsequently declines to very low levels by the age of 6 years. Nevertheless, most researchers agree that in late childhood/beginning of adolescence, the expression of food pickiness decreases (Dovey et al., 2008).

Concerning potential gender differences, pickiness appears to affect girls and boys equally (Carruth et al., 2004; Cole, et al., 2017; Taylor et al., 2015; Xue et al., 2015).

2-3- Measurement

Compared with food neophobia, not much attention has been paid to measuring food pickiness, which has been more often assessed clinically rather than psychometrically (Harris, 1993). Additionally, since there is no single widely accepted definition of pickiness, there is little consensus on an appropriate assessment measure (Cole et al., 2017). The methods used to identify pickiness fall into two broad categories:

(a) The use of item(s) from existing validated general questionnaires on food habits, that include scales for problematic eating, fussiness, food neophobia, low enjoyment when eating, and so forth. A broad range of different questionnaires is used. Notable questionnaires include the Children's Eating Behavior Questionnaire (CEBQ; Wardle et al., 2001; Tharner et al., 2014), the Lifestyle Behavior Checklist (LBQ; West & Sanders, 2009) or the Children's Eating Difficulties Questionnaire (CEDQ; Rigal et al., 2012).

(b) The use of a study-specific question(s). For example, some authors have recorded pickiness by simply asking parents whether their children are picky (Carruth, et al., 2004; Jacobi, Agras, Bryson, & Hammer, 2003).

It is interesting to note that, contrary to food neophobia, food pickiness seems to be exclusively measured via hetero-assessment methods and, to our knowledge, no studies have investigated whether caregivers are efficient to report their children's pickiness.

In the recent review of De Lauzon-Guillain and colleagues (2012), the authors found that most of existing scales measuring children's food pickiness are not entirely psychometrically sound. Only the CEBQ (Wardle et al., 2001) achieved all validity and reliability criterion, but only for one subscale, the "enjoyment of food" subscale. Moreover, the CEBQ does not differentiate between food neophobia and pickiness, while recent reviews and studies have proposed that they are two behaviorally distinct dimensions of children's food rejections (Dovey et al., 2008; Galloway et al., 2003; Rigal et al., 2012). Therefore, there is a need for further development of tools to measure pickiness in a more consistent and homogenous manner.

Finally, to date, and at least to our knowledge, food pickiness has not been assessed via behavioral food tasks.

3. What is the relationship between neophobia and pickiness?

While there are distinctions between the working definitions of neophobia and pickiness, it is not clear whether these aspects of children's food rejections are distinct or not. A controversy exists concerning the relationship between food pickiness and neophobia.

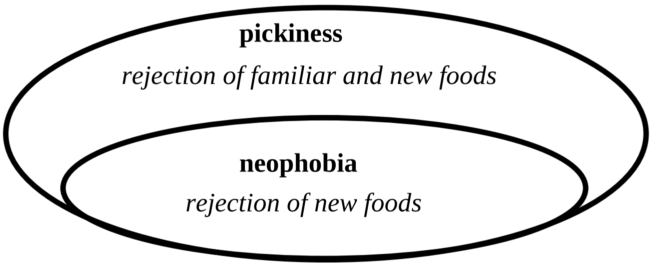
On the one hand, since food pickiness can be defined as the rejection of new and familiar foods, while food neophobia concerns only the rejection of new foods, the latter is sometimes considered to be a subset of pickiness (Dovey et al., 2008, see Fig.2a). More precisely, in their review, Dovey and colleagues (2008) assumed that food neophobia is part, but does not account for the entirety of picky eater's behavioral profile. They argue that, it is a necessary constituent of picky eating profile to be not willing to try new foods. They also argue that, the influence of food neophobia on a person's willingness to try new foods diminishes from the first taste processed as a positive experience. After this time, persistent rejection of texture for example, or an increased need for exposure for a child to accept a particular food she/he has already tried, must be considered as part of pickiness (Dovey et al., 2008). This inter-relationship will explain why some factors, such as parental practices, will have similar effects on magnitude, and duration, of both expression of neophobia and pickiness (Dovey, et al., 2008; Potts & Wardle, 1998; Randenbush, Van Der Klaauw, & Frank, 1995).

On the other hand, several authors claimed that food neophobia and pickiness are clearly distinct theoretically and behaviorally (Galloway et al., 2003; Pelchat & Pliner, 1986; Pliner & Hobden, 1992, see Fig.2b) as they have different predictors. In their study, Galloway and colleagues (2003) found that neophobia was predicted by mothers' neophobia and girls' anxiety, while pickiness was predicted by mother's variety in the vegetable intake and the number of months the child was breastfed.

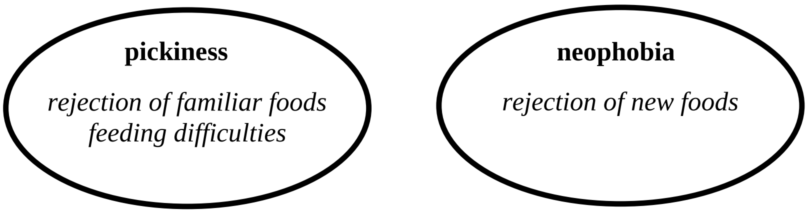
Finally, other authors argue that these constructs are indistinguishable (Wardle, et al., 2001). Nevertheless, these authors did not provide evidence or explanations for this absence of distinction (see Fig.2c).

Figure 2: Current views of the relationship between food neophobia and food pickiness.

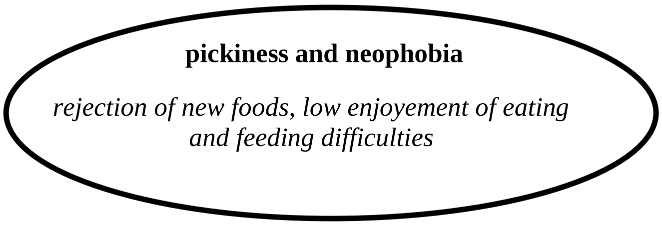
a.



b.



c.



The existing confusion concerning the relationship between food pickiness and neophobia is not surprising given the vagueness surrounding the very definition of pickiness (Potts & Wardle, 1998; Taylor et al., 2015). Nevertheless, from current definitions, two core distinctions seem to exist between food pickiness and neophobia:

(a) *The point of rejection of the food*. As previously mentioned, an important distinction between food neophobia and food pickiness is the point of rejection of the food itself. With pickiness, rejection does not occur only on mere sight but can occur after the tasting step. It is possible for certain authors that rejections occurring after the tasting step (understood as pickiness) are primarily rejections of the texture of the food. Indeed, texture can only be completely determined within the child's mouth, and pickiness if often associated with greater tactile sensitivity (Farrow & Coulthard, 2012). The rejection of certain textures is also possibly a rejection of perceived toxic foods, as certain textures, (e.g. slimy texture) inform about the decay of a food (Martins & Pliner, 2006).

(b) *The status of the rejected food*. The definitions of both kinds of food rejections depend on the notion of familiarity, which is however a view-point dependent concept. The concept of familiarity in its general sense refers to the cognitive ability to apply the knowledge gained through experiences with objects or stimuli (Aldrige et al., 2009). Parents cannot be acquainted with all their children's eating experiences. For instance, they might think their children have never tasted a given vegetable, while they had it in the childcare cafeteria. It is also highly possible that for a given child, changes in shapes, cooking or colors across recipes will make an already tasted vegetable appearing as a new vegetable (Aldridge et al., 2009; Rigal, 2010). Indeed, for a given child, a presented food can be genuinely new (never encountered before) but also perceived as new (encountered before but no feeling of familiarity is induced). For instance, a tomato tasted in purred baby food after weaning could be seen as a new vegetable for a child, when later presented whole. In this view, what appears as the rejection of foods that are supposedly familiar to children (understood as pickiness) might be in fact the rejection of food previously accepted but perceived as new by the child because of some changes in the recipe (Rigal, 2010). For some authors, this explains why mixed foods (which are difficult to recreate identically between servings) and fruits and vegetables (which are more prone to local or global changes between servings than other foods) are the privileged targets of food rejections (Brown & Harris, 2012; Carruth et al., 1998; Cashdan, 1998; Jacobi, et al., 2003). While it could be argued that low vegetable intake is due to their bitter taste (Rosentein & Oster, 1988), or low fruit intake explained by the low energy provided (Gibson & Wardle, 2003), neither of these arguments can be applied to the rejection of mixed foods. Together, the findings show a pattern of rejection of foods prone to perceptual changes between servings (Brown, 2010).

To investigate whether what appear as two distinct constructs would capture a same kind of fear for new and potential toxic foods, further studies are needed to investigate the notion of novelty and familiarity food rejections depend on, as well as to investigate what exactly are the bases of rejection in the case of rejection after the tasting step.

4. Conclusion

The two strongest psychological barriers to increase a child's dietary variety seem to be food neophobia (defined as the reluctance to eat new foods; Pliner & Hobden, 1992) and pickiness (defined as a restricted intake of new and familiar foods and rejection of certain textures; Taylor et al., 2015). Nevertheless, there is clearly still some confusion surrounding the concept of pickiness (Cole et al., 2017; Potts & Wardle, 1998; Taylor et al., 2015). This arguably partly explains the lack of an appropriate assessment measure of pickiness and consensus regarding the relationship between food neophobia and pickiness.

This uncertainty is reinforced by the apparent absence of projects to design and validate a common scale including both pickiness and food neophobia as two possible dimensions of food rejections by children. This is a major gap in the field of childhood eating behavior assessment, which would be worth filling.

Finally, as pointed out by several authors (Hollar, et al., 2013; Laureati et al., 2015), the availability of scales for assessing food neophobia and pickiness is crucial to the understanding of the mechanisms underpinning these kinds of food rejections.

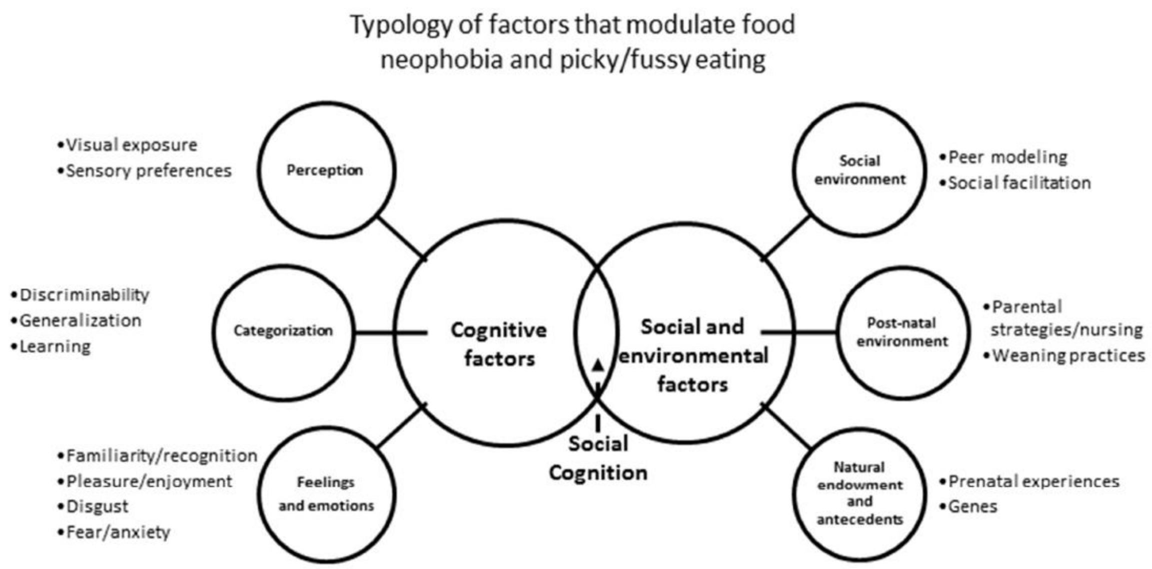
Chapter 2. Understanding the appearance and development of food rejections

Despite extensive research in the field of food sciences, all the factors influencing food neophobia and pickiness have not been clearly identified yet. The second chapter of this thesis first reviews the range of factors identified to play a key role in these two kinds of food rejections in childhood, and then emphasizes on cognitive factors as they appear to be important determinants in the formation of children's food acceptance. The previous chapter revealed that while there are distinctions between the working definitions of neophobia and pickiness, it is not yet clear whether these aspects of children's food rejections are theoretically distinct or not. The present chapter then presents factors that have been shown to influence neophobia, pickiness or both.

1. Overview of identified factors involved in children's food rejections

A recent review conducted by Lafraire, Rioux, Giboreau and Picard (2016) presents a typology of the factors involved in food neophobia and pickiness (see Fig.3). The authors distinguished two kinds of factors: social and environmental factors and cognitive factors.

Figure 3: Typology of factors that modulate food neophobia and pickiness (retrieved from Lafraire et al., 2016).



1-1 - Social and environmental factors involved in children's food rejections

As presented in Fig. 3, food rejections are influenced by social and environmental factors (Addessi, Galloway, Visalberghi, Birch, 2005; Dovey, Staples, Gibson, & Halford, 2008; Harper & Sanders, 1975). For instance, parental feeding strategies are known to shape children food rejections. Commonly used practices, such as food rewards, have negative impact on children food neophobia and pickiness (see DeCosta, Møller, Frøst, & Olsen, 2017 for a review of the effects of rewards on young children food behaviors).

Another far and wide studied social factor is social facilitation, defined as an increase in the probability of performing a class of behavior, in the presence of conspecifics performing the same class of behavior, at the same time (Clayton, 1978; see Herman, 2015 for a review of the food social facilitation effects). It has been shown that toddlers are more willing to taste a new food if they seen an adult eat it first (Addessi et al., 2005; Hendy & Raudenbush, 2000). In addition, social facilitation is enhanced when models are familiar to children (Harper & Sanders, 1975) and are "prosocial" (Hamlin & Wynn, 2012). It is interesting to note that, in human children, social facilitation effects are specific and limited. Children accept a new food through observing others eating the same food, but not if the food is different (Addessi et al., 2005). By contrast, capuchin monkeys accept a new food even if models are eating a differently colored food (Addessi & Visalberghi, 2001).

Several studies also proposed that the antecedents of the child (child's genes and prenatal food experiences) play an important role in children's development of food rejections. Regarding prenatal experiences, evidence suggests that children are more willing to taste new flavors if they have experienced them through amniotic fluid and breast milk (Mennella, Jagnow, & Beauchamp, 2001).

1-2 - Cognitive factors involved in children's food rejections

Lafraire and colleagues' review (2016) also presents the cognitive factors (used in the review in the broad sense of the term, i.e. including perception and emotional-temperamental factors), that can influence food rejections (see Fig 3). It has been shown that visual and olfactory cues play an important role in the evaluation of food, and have a key role in food rejections, since they appear primarily on sight (Dovey et al., 2008). For instance, Macario (1991) reported that many parents have anecdotally noted that their children can reject all foods of a particular color.

To explain these mechanisms, Macario (1991, Exp. 2-3) showed 2- to 4-year-old children two photographs of familiar foods: one normally colored (e.g., a green lettuce) and one anomalously colored (e.g., a purple lettuce). The children were asked which one was not for people to eat, and consistently chose the anomalously colored photograph. The author concluded that the rejected foods were those that were not the color they were supposed to be.

Lafraire and colleagues (2016) also pointed out that food rejections can be partly explained by personality traits such as tactile defensiveness (i.e., overreactions to the experience of touch, and withdrawal responses to some typically inoffensive tactile stimuli, perceived as offensive). It has been shown that tactile defensive children refuse vegetables to a higher degree than non-tactile defensive ones (Smith, Roux, Naidoo, & Vender, 2005).

Completing the typology of cognitive factors presented in Fig 3, some researchers have proposed that food rejections and neophobia in particular could be a direct consequence of one specific dimension of temperament: approach/withdrawal (Moding & Stifter, 2016). This dimension characterizes individual differences in response to new stimuli, such as toys, people or situations. Children who are low in approach tend to show negative affect toward new stimuli and withdraw from them (Rothbart & Bates, 2006). In their longitudinal study, Moding and Stifter (2016) showed that children with low approach tendencies at 18 months had higher levels of food neophobia at 4.5 years of age.

1-3 - Avenues for future research

Beyond a review of the factors influencing the development of food rejections, one important contribution of Lafraire and colleagues' review (2016) is to point out that there has been a large discrepancy in the number of studies investigating social factors on the one hand and studies investigating cognitive factors on the other hand. The latter being far less studied so far. This discrepancy was also acknowledged by a recent review on food learning in infancy (Mura Paroche, Caton, Vereijken, Weenen, & Houston-Price, 2017). Precisely, Lafraire and colleagues highlighted that food rejections, present to some extent in at least half of typically developing children (Hanse, 1994), appear roughly at the same period that rapid changes and improvements appear in the child's food categorization system (Brown, 2010). For the authors, this concomitance may not be a sheer coincidence and calls for further investigation. Categorization is a fundamental cognitive process that allows us to organize objects into groups (Vauclair, 2004). When a food item is first presented to a child, it is organized into categories relating to its characteristics (Murphy, 2002; Vauclair, 2004). Knowledge gained through this first encounter allows for easier and faster categorization when subsequently presented with the same, or a similar food item, triggering a feeling of familiarity (Aldridge, Dovey, & Halford, 2009). Future studies might then assess the developmental characteristics of children's food categorization system during the sensitive period for food neophobia and pickiness (2-6 years of age).

In his brilliant rebuttal of Skinner's analysis of verbal behavior (1959), Chomsky claimed that "the fact that all normal children acquire essentially comparable grammars of great complexity with remarkable rapidity suggests that human beings are somehow specially designed to do this (…). A refusal to study the contribution [of the cognitive structures] of the child to language learning permits only a superficial account of language acquisition". These past few years, in accordance with Chomsky's thinking, research in food behaviors drew closer to research in conceptual development (Aldrige et al., 2009; Brown, 2010; Grisphover & Markman, 2013; Houston-Price, Burton, Hickinson, Inett, Moore, Salmon, & Shiba, 2009; Lafraire et al., 2016; Mura Paroche et al., 2017; Zeinstra, Koelen, Kok, & De Graaf, 2007), and is increasingly in favor of the opening of the "black box" to fully understand food behaviors and hence one important facet of these behaviors : food rejection.

2. Why studying especially food categorization development during the sensitive period for food rejections?

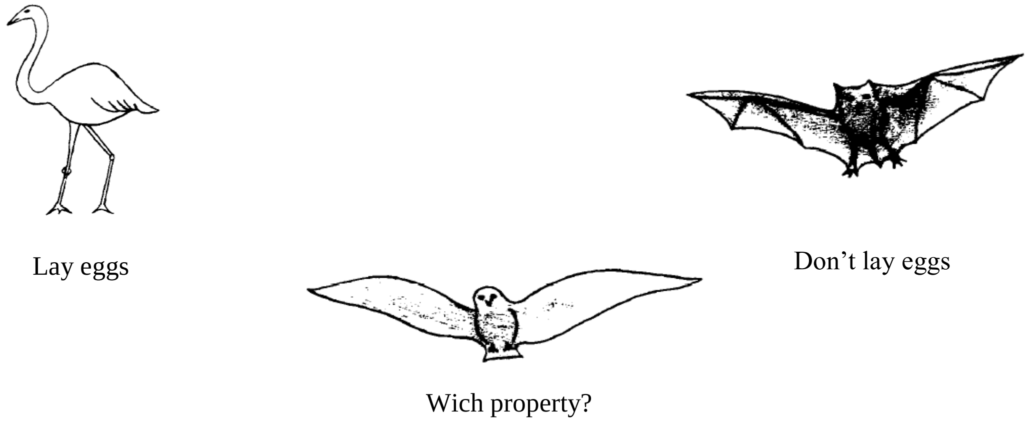
To better grasp the putative importance of food categorization development in the appearance of food rejections, we first need to focus on one central use of categories, which is to make predictions about new items (referred as *category-based induction*; Feeney & Heit, 2007). For example, if an adult is presented with a new instance of a tomato never encountered before (or a new instance of a fruit), she/he will be able to infer its properties (e.g., *edible*, *tasty*, *safe to consume,* etc.) from the knowledge of the tomato category (or the fruit category). By allowing us to disregard insignificant perceptual differences across exemplars (size, color, etc.), categories enable us to take advantage of our past experiences, and to generalize our knowledge to new instances or new situations. Thereby, categories avoid us the need to examine each and every object or situation *de novo* (Feeney & Heit, 2007; Murphy, 2002).

2-1- Category-based induction in young children

So far, there has been little focus on category-based induction among preschoolers within the domain of food (see Nguyen and collaborators' studies for exception; Nguyen & Murphy, 2003; Nguyen, 2007; Thibaut, Nguyen, & Murphy, 2016). Nevertheless, a large body of research (Gelman & Davidson, 2013; Gelman & Markman, 1986; Welder & Graham, 2001) has documented children's early reliance on category membership when making predictions about new items within the natural kind domain. In addition, researchers have found evidence for reasoning about fruits and vegetables as natural kinds (Gelman, 1988; Rumiati & Foroni, 2016; Foroni & Rumiati, 2017).

In their seminal triad paradigm, Gelman and Markman (1986) asked 4-year-old children to perform novel property generalization about natural kind items (e.g., birds) when perceptual and categorical items of information were pitted against each other. For example, children were asked whether an owl was more likely to lay eggs like a flamingo, because they both belong to the bird category, or don't lay eggs like a bat, because they look alike (see Fig.4). Rates of category-based responses (such as "owl are more likely to lay eggs like flamingo") were above chance level. The authors concluded that young children can use category membership to support induction, even when it conflicts with visual features. Using a simpler procedure, the authors discovered a tendency to prefer category membership over perceptual similarity at 3 years of age (even if category labels were not provided, Gelman & Markman, 1987) and in children as young as 2 years of age (Gelman & Coley, 1990).

Figure 4: Classical triad paradigm of category-based induction task (retrieved from Gelman & Markman, 1986).



Additionally, by the preschool age, children are aware that certain properties are more generalizable than others. Gelman (1988) found that, from 3 years of age, children did not generalize transient or non-generalizable properties of an instance of a carrot and an apple like *has a little scratch on it* or *came from Nevada* to other members of the category. Conversely, they generalized biological or functional properties like *has pectin inside* or *can use it to make a sauce called chutney*.

Therefore, by the time food rejections develop, children seem to be able to engage efficient category-based induction, and to infer, for instance, that a tomato never encountered before has the biological and functional properties of other members of the category (i.e., *being edible*, *being sour*, *can be used for tomato sauce* etc.).

2-2- Individual differences in category-based induction

While past induction studies of natural kind concepts suggested that children rely on category membership to draw induction from an early age, only a minority of children could be reliably classified as constant category-based responders. For example, in Gelman and Markman's study (1986), only 31% were classified as such by the age of 4 (as defined by the authors). Constant category-based responders inferred the properties of new items based on category membership-and not perceptual similarity- for at least 15 out of 20 items.

To explain the variability among same-age children, several researchers suggested that children's inductive abilities differ according to their experience and conceptual knowledge (Chi, Hutchinson, & Robin, 1989; Fisher, Godwin, Matlen, & Unger, 2015; Gelman & Markman, 1987). For instance, when presented with new exemplars of dinosaurs, children classified as *dinosaur experts* (i.e., those who had prior knowledge about dinosaurs) tended to make category-based induction. For instance, a child said that a new exemplar of a dinosaur labeled *duckbill* was probably "a good swimmer because *duckbills* are good swimmers". By contrast, *novices* were likely to make induction based on a salient perceptual feature of the exemplar. For instance, a child said that a new exemplar of dinosaur labeled *duckbill* "could probably walk real fast because he has giant legs". In the same vein, recent research has revealed that category-based induction abilities are strongly correlated with semantic development. Among same-age individuals, those with more sophisticated semantic knowledge performed better on a category-based induction task (Fisher, Godwin, & Matlen, 2015; Fisher, Godwin, Matlen et al., 2015). Finally, Gelman and Markman (1987) found that children drew induction from one category member to another on those items for which they could detect the category membership of the pictures involved.

Hence, it seems that the more sophisticated a child’s knowledge is in a given domain, the more likely a child is to engage in category-based induction, and may disregard perceptual similarities, to predict properties for a new item in that domain. In the food domain, it is possible to assume that, when presented with a new instance of a tomato, a child with poor food knowledge will have difficulties categorizing it as a tomato and inferring edibility, or other biological or functional properties, of the new instance.

3. Developmental characteristics of children's categorization system during the sensitive period for food rejections

Categories support inductive reasoning and induce a feeling of familiarity (Aldridge et al., 2009; Gelman & Markman, 1986); once a new food instance is subsumed under a certain food category, the properties featuring in the informational content of the category may be extended to the new instance (such as the property *edible* for a new tomato). Therefore, we need to examine how children in the sensitive period for food rejections subsume a new item into a given category and to examine the nature of their food category. Investigating the nature of children’s categories imply to investigate both the structure and the content of these categories. The structure of the category refers to how knowledge is organized and represented in our mind (e.g. prototype-based or exemplar-based structure, see section 3-2). The content of the category is the different properties of the prototype (if one endorses the prototype theory, see section 3-2).

3-1- Thematic, script, and taxonomic categories

Researchers have identified several kinds of category that are used to group the different objects surrounding us (Bonthoux, Berger, & Blaye, 2004; Nguyen & Murphy, 2003; Nguyen, 2007).
(i) Thematic categories. These categories group objects that have complementary relationships and that often are spatially, and temporally contiguous. For example, a fork and a steak, because a fork is usually used to eat the steak.
(ii) Script categories. These categories are formed with objects playing the same role in a

schema or a script. For instance, eggs and cereals are both in the script category of breakfast foods, as they are both kinds of foods eaten at breakfast.

(iii) Taxonomic categories. These categories are based on common properties shared by the members of the category. For instance, tomatoes are in the same category because they grow on plants, contain vitamins, are sour, etc. An additional important feature of taxonomic categories is that they are organized into hierarchies of increasingly abstract categories (Rosh, 1973) (such as: cherry tomato-tomato-vegetable-food, where cherry tomatoes are a type of tomato, which are a type of vegetable which are a type of food). Categories high in the hierarchy are *superordinate* categories (e.g., foods, vegetables); those in the middle are *basic level* categories (e.g., tomatoes), and the ones low in the hierarchy are *subordinate* categories (e.g., cherry tomatoes). Every property true for the members of a category is also true for the category's subordinates (e.g., if all tomatoes are sour, then all cherry tomatoes are sour as well). Even though superordinate categories are more computationally demanding than basic level ones, it has been argued that by the end of the second year of life, when food rejections appear, children can categorize at the superordinate level (e.g., animals and vehicles or fruits and vegetables) and at the basic level (e.g., fishes and dogs or apples and pears; Mandler, Bauer & McDonough, 1991).

Early work on categorization development has assumed that taxonomic categorization was the mature form of categorization and that young children were only using thematic or script categories until 7 or 8 years of age (Inhelder & Piaget, 1964). Nevertheless, it is now quite a consensus that certain taxonomic categories, such as animal or food categories, are used early in development (Mandler et al., 1991; Murphy, 2002; Nguyen & Murphy, 2003; Nguyen 2007), and definitively before the onset of food rejections. Thematic or script relations are extremely important to learn about for some purposes (for example, children do learn to get a fork when eating a steak). Nevertheless, several studies have found that children preferentially rely on taxonomic categories when reasoning about the effects of eating and to represent nutritional or biochemical knowledge (Nguyen & Murphy, 2003; Thibaut et al., 2016). Consequently, only taxonomic category development is considered for the remaining part of this chapter.

3-2- Category structure: exemplar vs. prototype

The literature on adult categorization has been dominated in the past decades by the lively debate on whether categories were based on exemplar or prototype structure. However, most research on children categorization development seems to take, at least implicitly, a prototype view of category organization (Murphy, 2002). In this account, a given category is represented by a summary representation, the *prototype* of the category, which is a unified representation rather than separate representations for each member of the category (Rosch, 1973). In the contrary, the exemplar theory claims that one's concept of apple, for instance, is the set of all the exemplars of apples that the person encountered and remembers, i.e. a set of 200 hundred apples memories (Medin & Schaffer, 1978).

The prototype theory states that the prototype possesses all the properties of the category (for example, the prototype of the tomato category possesses the properties *edible*, *round*, *contain vitamins, red*…). These different properties (or features) have different weights (or importance). The prototype of the tomato category is therefore not a tomato that we have already met, but rather a collection of properties characteristic of the tomatoes already encountered, with the property *edible* having a greater weight than the property *round,* or the property *red* a greater weight than the property *green* (Murphy, 2002).

3-3- The phenomenon of typicality

Within the prototype theory framework, items that share many properties with the prototype (or few but properties with high weight) are more typical of the category that items that share fewer properties with the prototype. For instance, an oriole tends to fly, have a common size for a bird, and perches on trees as most birds do. Thus, even if we have never seen an actual oriole, we can identify it as a typical instance of the bird category. In contrary, the familiar chicken, which does not possess these important (in term of weight) properties, is not identified as a typical bird (Rosch & Mervis, 1975).

This phenomenon of *typicality* is fundamental when one is interested in categorization development and performance. Meints, Plunkett, and Harris (1999) showed for instance that 12-month-old children could correctly identify typical members of named categories, but not atypical ones. Children were shown a picture of a dog next to a picture of a bird while hearing

“Look at the dog!”. They did look at the dog when it was a typical one, but not when it was atypical. Additionally, children learn better if they are taught with typical items (Mervis & Panis, 1980), and atypical items of a given category are frequently excluded from that category (Murphy, 2002).

Thus, the typical items have a privileged place in the categorical representation of children and the degree of typicality to each member of a category is extremely stable between different persons (Barsalou, 1985; Rosch, 1973; Rosch & Mervis, 1975). For instance, green beans and carrots are viewed as highly typical vegetables, while sprouts and avocados are view as atypical ones (Barsalou, 1985). So most 2-year-old children would probably view a red fist-sized tomato more typical of the category tomato than a yellow cherry-tomato; categorization should be easier for the former.

3-4- Categorization of a new item

In the prototype account, children categorize new items with similarity computation between the presented item (for instance, a green round tomato), and the weighted property list. If the presented item has enough properties in common with the prototype, pondered by the properties’ weights, then it is judged in the category, if not, it is not. Hence, the more highly weighted features an item has, the more likely it is to be identified as a category member (Murphy, 2002).

The determination of a property’s weight is based on empirical experience and associative mechanisms, capable of extracting statistical regularities from the input and environment (Mareschal, 2003; Sloutsky, 2003; Smith, Colunga, & Yoshida, 2003). For example, if children see tomatoes a dozen times, and for ten of those times they can see red colors, they would likely conclude that being red is an important property of that category (i.e. a property with a high weight). Additionally, property-property co-occurrences appear readily learnable (Smith & Colunga, 2012). Links between properties that frequently co-occur in the input are strengthened, while those between relatively infrequent variable properties are not. Certain expectations then develop, so that on presentation of one property (or more) a child will expect that other properties that have been correlated with that one in the past, to be also present (Smith & Colunga, 2012).

Some researchers propose that this determination of a property’s weight based on empirical experience is the sole mechanism explaining category learning (Mareschal, 2003). In this view, labels are mere features (or properties) of the prototype. Since there is less variability in label use than in perceptual appearance in a category of objects, children empirically learn, as they encounter items, that labels are better predictors of category membership (or have higher weight) than perceptual features (Mareschal, 2003).

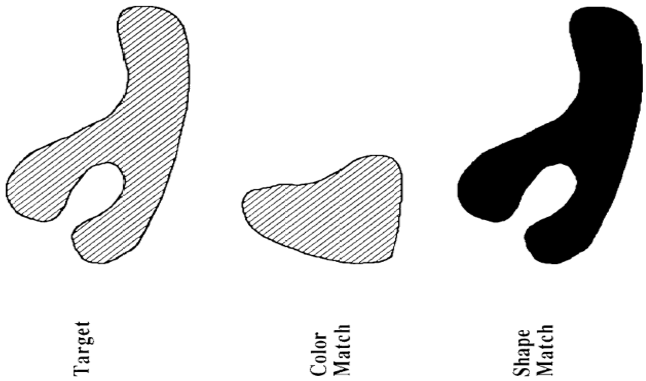
Nevertheless, for numerous researchers, proponent of the theory theory (this theory was built upon the prototype theory), sole unconstrained feature covariance, and computation based on similarity, do not provide a satisfying account for categories development (Murphy, 2002). For these authors, there are too many possible feature correlations in a child's environment (Murphy & Medin, 1985). The probability of accepting new instances as category members is also dependent on theoretical beliefs or knowledge (Gelman & Koenig, 2003; Gopnik & Nazzi, 2003; Keil, 1989; Markman & Jaswal, 2003; Murphy, 2002). Categories are part of our general knowledge about the world and we don't learn categories in isolation from everything else. Rather, we learn them as part of our overall understanding of the world around us (Murphy, 2002; Thibaut, Gelaes, Cordier, & Meunier, 2005). If a property you learn about a new tomato does not fit with your general knowledge, you may question it or give it less weight. Theories (abstract, coherent, causally organized, and ontologically committed bodies of information, Gopnik & Nazzi, 2003) help identify those properties that are relevant to a category and they constraint how similarity should be computed. Within this theory theory account, and in the natural kind domain, it is thought that although perceptual similarity surely plays a role, children believe that defining properties based on biology (internal structure, function…) dominate characteristic properties (appearance) to define category membership. In this view labels are category markers, and are not mere category features: a common label suggests a common category (e.g., if two items are called *apple* then they belong to the same category). According to Keil, children believe in the *essentialism* of categories (Keil 1989): children may infer hidden causes for overt events and, in particular, an essential property that makes a thing what it is. In a series of studies, Keil (1989) ask children to consider animals that had undergone transformations leading them to appear to be something else. For instance, they were told that a raccoon underwent an operation, so that it looked like a skunk. 7-year-old children realized that animal category was unaffected by superficial features (e.g., the animal was judged to be a raccoon despite it looked like a skunk). Similarly, Gelman and Wellman (1991) found that 3-year-old children appreciated that for natural kinds "insides" are more important than "outsides" for judgments of category.

3-5- Specificity of the food domain in categorization development

Regardless of which view of category one endorses there is nevertheless clear agreement that perceptual features are routinely used to identify category members (Markman & Jaswal, 2003). This is especially true when children encounter objects and categorize them without external feedback. Indeed, as from 2-year-old children can encounter foods without their caregivers' supervision and therefore the only available information is perceptual information. To act effectively, children need to focus their attention on cues that are relevant to the problem at hand (e.g., deciding to eat or not a new food instance). Some researchers have proposed that humans are endowed with a collection of specialized learning systems that biases and guides their attention to domain relevant perceptual inputs (Santos, Hauser, & Spelke, 2002). According to this approach (viewed as the *core knowledge* theory, see Spelke & Kinzler, 2007; Carey, 2009), children are born with a set of specific learning systems. These systems are innate, domain-specific (designed to handle a specific type of information that is not processed in the same manner by other type of systems) and thought to have evolved in response to the computational problems that were most salient over our phylogenetic history. Innateness associated with this theory does not necessarily mean "present at birth" but rather "does not require learning" (Carey, 2009).

Recently some researchers have hypothesized that humans are endowed with such a system for food categorization (Santos et al., 2002; Shutts Condry, Santos, & Spelke, 2009). Indeed, one important finding in the domain of food categorization is that children from the age of 2-to 3 years attend to information about color or texture rather than shape (Landau, Smith, & Jones, 1988; Yoshida & Smith, 2003) when discriminating between edible and inedible substance or between different kinds of foods (Foroni & Rumiati, 2017; Lavin & Hall, 2001; Macario, 1991; Shutts et al., 2009). For example, in a conflicting picture triad procedure, Macario (1991, Exp. 4) showed 3- to 4-year-old children a new object, described as either a thing to eat (*food* condition) or a thing to play with (*toy* condition). The children were then introduced to two other new objects: a color-match with the target object; and a shape-match with the target object (see Fig. 5). When asked which one was like the target object, children were more likely to choose the color-match object in the *food* condition, whereas they were more likely to choose the *shape-match* object in the *toy* condition.

Figure 5: Macario's experimental stimuli. The target is the thing to eat or play with (retrieved from Macario, 1991).



Similar findings have been found for rhesus monkeys (Santos, Hauser, & Spelke, 2001; Shutts et al., 2009) and have been reported not only in nonlinguistic categorization tasks, as in Macario's study, but also in new word extension tasks (Lavin & Hall, 2001)[3]. Additionally, a recent neuropsychological review on food representations reporting how brain-damaged patients recognize food and nonfood items, suggested that representations of foods dissociate from representations of animals or other living things (Rumiati & Foroni, 2016). These data speak in favor of a domain specificity effect on food categorization.

To further clarify the concept of domain-specificity, it is important to introduce the distinction between the *proper* and *actual* domain of a domain-specific system (Sperber, 1994). The proper domain of a domain-specific system (or module) is "all the information that it is the module's biological function to process" (Sperber, 1994, p.52). Therefore in the case of the food categorization system, its proper domain is all the comestible food stimuli in our environment. To recognize stimuli belonging to its proper domain, a module uses input conditions that a stimulus has to meet in order to be accepted and processed (for instance a particular food item has to be accepted in the food category). A stimulus belonging to the proper domain of the module may fail to satisfy the input conditions (referred as a *miss*, such as a durian fruit not accepted in the food category because it is a highly atypical fruit). On the other hand, a stimulus not belonging to the proper domain of a module may nevertheless satisfy its input conditions (referred as a *false alarm*, such as a venomous mushroom; Sperber & Hirschfeld, 2007). The actual domain of a module is then all the stimuli that "may satisfy the module's input conditions"

[3]Food seems also to be a unique domain in social cognition. As proposed by Lumeng and collaborators children use social information differently to make a choice about a food as compared to a non-food (Lumeng, Cardinal, Jankowski, Kaciroti, & Gelman, 2008).

(Sperber, 1994, pp.51-52). In other terms, it is not because a certain stimulus is processed by a specialized cognitive system that it is the biological function of this system to process it and that, whatever the particular domain-specific cognitive system at hand, its proper domain rarely coincides with its actual domain.

If there is a domain-specific system for representing food, it nevertheless differs from other systems of core knowledge by emerging rather late in development. Indeed, using a looking time procedure, Shutts and colleagues (2009) failed to show that 9 months of age infants preferentially attend to color information over shape information when reasoning about food. They showed that infants directed their attention equally to domain-relevant properties (e.g., color and texture) and to domain-irrelevant properties (e.g., shape of the food's container). Additionally, using both a sequential touching procedure and a forced sorting task, Brown (2010) found that before 20 months, infants did not systematically distinguish between food and animal categories (see Fig. 6). By contrast, signatures of other core systems have been uncovered in 3- to 4-month-old infants (Spelke & Kinzler, 2007).
This seems nevertheless conceivable since infants have a long period of nursing and rely on caregivers to guide their food choices until 2 years of age approximately. Therefore, they may not need mechanisms for determining whether a food is safe or hazardous to eat in early infancy (Shutts et al., 2009). In fact, a rapid change occurs at the end of the second year of life. Indeed, in Brown's experiment previously described (2010), he found that after 22 months, infants distinguished between food and animal categories (see Fig. 6). Similarly, using a sorting task procedure, Bovet, Vauclair, and Blaye (2005) found that 30-month-old children systematically distinguished between toys and foods. Additionally, using a rapid categorization task, Lafraire, Rioux, Roque, Giboreau and Picard (2016) found than 3-year- old children could sort foods from color-match artifacts. Nevertheless, their performances were still moderate: children had a high hit rate (80%), but also a high false alarm rate (50%; Lafraire, Rioux, Roque et al., 2016). Finally, Brown (2010) established that, at this age, children also differentiate between categories within the food domain, such as biscuit and fruit categories.

Figure 6: Brown's experimental stimuli. Infants had to sort into two boxes this set of objects (retrieved from Brown, 2010).

Interestingly, and as pointed by Lafraire, Rioux, Giboreau and colleagues (2016), food rejections peak precisely when rapid changes and improvements appear in the child's food categorization system. This concomitance, as well as the fact that rejections occur mainly on the mere sight of the foods when no feeling of familiarity is present (Aldridge et al., 2009, Mura Paroche et al., 2017), lead some authors to hypothesize a relationship between these two phenomena. As children wish to recognize the foods they are given (to be sure of the consequences of ingestion), a mismatch between the presented food and the prototypical food representations will possibly lead to food rejection (Brown, 2010; Dovey et al., 2008). For instance, Brown (2010, p. 85) hypothesized that "children have developed a prototypical expectation of a food (…) and if what is presented induces a perceptual mismatch to that expectation, the food may be rejected". Similarly, Dovey and colleagues (2008) hypothesized that "children build up schemata of how an acceptable food should look, and perhaps smell, and so foods not sufficiently close to this stimulus set will be rejected".

4. Conclusion

Food neophobia and pickiness are influenced by social and environmental factors on one side, and cognitive factors on the other side. Nevertheless, there has been a large discrepancy in the number of studies investigating social factors compared to studies investigating cognitive factors. The literature reviewed above shows that investigating categorization development in children could be an interesting avenue for further research, to better grasp the mechanisms underpinning food neophobia and pickiness. The concomitance of the development of food categorization and appearance of food rejections lead some authors to hypothesize that, as children wish to recognize the foods they are given, a mismatch between the food that is presented and their prototypical food representations will lead to food rejection.

Given the widening gap between children's actual consumption of fruits and vegetables and recommended intakes (Cockroft, Durkin, Masding, & Cade, 2005), only a thorough understanding of the mechanisms underpinning food rejections will supplement the full range evidence-based practices for encouraging healthy eating habits in children.

Chapter 3. Overcoming food rejections

Various reviews of existing interventions show that certain strategies efficiently enhance fruit and vegetable acceptance and liking, and decrease food rejections (Appleton, et al., 2016; Evans, Christian, Cleghorn, Greenwood, & Cade, 2012; Keller, 2014; Knai, Pomerleau, Lock & McKee, 2005; Perez-Rodrigo & Aranceta, 2001). Changes in children's food preferences, once foods are accepted, are out of the scope of the present thesis. Therefore, only efficient strategies that enhance acceptance of fruits and vegetables are presented in this third chapter. Moreover, because cognitive factors seem important, interventions based on environmental changes (i.e., increase in vegetable availability, change in parental practices, etc.), rather than on individual changes (i.e., increase in nutritional knowledge, etc.), are not developed in this chapter. For recent reviews on these interventions see for instance Appleton and colleagues (2016) or DeCosta , Møller, Frøst and Olsen (2017).

1. Which strategies exist to overcome food rejections?

Three kinds of strategies based on individual changes are widely used to decrease food rejections: Flavor-Flavor Learning (Havermans & Jansen, 2007; Remy, Issanchou, Chabanet, & Nicklaus, 2013), Flavor-Nutrient-Learning (Caton, Ahern, Remy, Nicklaus, Blundell, & Hetherington, 2013; Johnson, Mcphee, & Birch, 1991) and Mere Exposure (Anzman-Fresca, Savage, Marini, Fisher, & Birch, 2012; Wardle, Cooke, Gibson, Sapochnik, Sheiham, & Lawson, 2003). 90% of the interventions based on individual changes adopted at least one of these methods (Appleton et al., 2016).

Flavor-Flavor-Learning (FFL) and Flavor-Nutrient-Learning (FNL) are two strategies based on Pavlovian conditioning: an association between a neutral conditioned stimulus and a positive unconditioned one will trigger a positive attitude toward the conditioned stimulus, even when the unconditioned stimulus is latter removed. The principle of FFL is that the pairing of a target food (often a new or disliked vegetable), with a taste that is already liked, should trigger positive attitude toward the target food. For instance, Remy and colleagues (2013) proposed sweetened artichoke puree to infants, to examine the acceptance of the target food (artichoke) when it was paired with a liked taste (sweet), compared to plain artichoke puree.

The principle of FNL is that the pairing of a target food, with a food with high energy density, should trigger positive attitude toward the target food. Caton and colleagues (2013) proposed artichoke puree enriched in fat to infants, to examine the acceptance of the target food (artichoke)

when it had a higher energy density, compared to plain artichoke puree.
Both FFL and FNL have been showed to positively enhance fruit or vegetable acceptance in children (Ahern, Caton, Blundell, & Hetherington, 2014; Caton et al., 2013). Caton and colleagues (2013) found that infants accepted more plain artichoke puree at post-test, compared to baseline, when they had been offered ten times artichoke puree enriched in fat.

According to the Mere Exposure theory (ME), the exposure to one instance of a given food stimulus is sufficient to trigger a more positive attitude toward a subsequent instance of that particular stimulus, because it increases its familiarity (Zajonc, 1968). There is considerable support for the success of such ME on food acceptance in controlled experimental settings (Birch & Marlin, 1982; Birch, Mcphee, Shoba, Pirok, & Steineberg, 1987), as well as in more ecological settings like home or school environment (Mustonen & Tuorila, 2010; Park & Cho, 2015; Wardle et al., 2003). Moreover, ME effects have been demonstrated across cultures, in several species (e.g., rats), and with various types of stimuli (e.g., foods, Chinese ideographs, abstract paintings, photographs of human faces etc.; Cooke, 2007; Zajonc, 1968). For instance, Birch and Marlin (1982) found that, children who had been exposed to five new fruits were more likely to choose to eat them in a consequent choice trial, compared to children not exposed to new fruits. Wardle and colleagues (2003) asked caregivers to expose their 5-to 7-year-old children to bell peppers for eight consecutive days, and found that compared to a control group, children in the exposure group ate significantly more bell peppers at post-test than at baseline.

Despite the apparent efficiency of these three strategies (FFL, FNL, ME), it has been argued that conditions within studies are often confounded and that, in many studies that purported to measure conditioning effects, exposure was actually not controlled for (Appleton et al., 2016). In fact, studies comparing directly these three strategies often found no advantage of conditioning over mere exposure (Ahern et al., 2014; Bouhlal, Issanchou, Chabanet, & Nicklaus, 2014; Caton et al., 2013; Hausner, Olsen, & Moller, 2012; Remy et al., 2013). Caton and colleagues (2013) found that infants who had been exposed to plain artichoke puree (ME condition) accepted plain artichoke puree as easily at post-test, as children who had been exposed to sweetened puree (FFL condition) or puree enriched in fat (FNL condition). As mere exposure interventions are easier to implement and seem to be as effective as FFL/FNL interventions, ME appears to be the simplest choice to enhance positive attitude towards fruits and vegetables and to decrease food rejections (Appleton et al., 2016; Bouhlal et al., 2014). Additionally, this strategy is not very demanding for the exposed children themselves (Zajonc, 2001).

2. Mere taste exposure

2-1-What constitutes an exposure in the food domain?

In the food domain, an exposure can occur in different modalities (taste, sight, smell etc.). The majority of studies on ME have only investigated whether *taste* exposure will be efficient to decrease food rejections and enhance the consumption of fruits and vegetables (Cooke, 2007; Dazeley, Houston-Price, & Hill, 2012). This central interest in taste exposure is probably due to the seminal study of Birch and colleagues (1987). The authors directly compared the effect of visual and taste exposure on preschoolers liking for new fruits. They found that visual exposure led to an increase in liking for the appearance of the new fruits, while taste exposure led to an increase in liking for both the appearance and taste of the new fruits (Birch et al., 1987). Subsequent research on ME then focused on taste exposure as it was thought to be necessary to enhance consumption of fruits and vegetables.

Nonetheless, within interventions focusing on the taste modality, children can be exposed to a small taste or a bite (which may or may not be swallowed), a full feeding, etc. There is an important variability across studies (Keller, 2014) and no consensus exists so far regarding exactly what constitutes a food exposure, at least for the taste modality.

2-2-How many exposures are needed to enhance acceptance?

To date, another contention exists regarding the number of exposure needed to enhance food acceptance (Anzman-Frasca et al., 2014; Keller, 2014; Lakkakula, Geaghan, Zanovec, Pierce, & Tuuri, 2010). This is possibly stemming from the fact that research on ME has seldom been designed to test how many exposures are necessary and sufficient (Anzman-Frasca et al., 2014). Additionally, this confusion may be partly due to the fact that in many studies, the actual number of taste exposure is reduced because children refuse to taste the proposed food a certain number of times during the intervention (Keller, 2014; O'Connell, Henderson, Luedicke, & Schwartz, 2012). Therefore, 10-exposure paradigms in a laboratory or school setting will likely result in fewer than 10 tastings and, the actual number of exposures will likely differ from one child to another.

Interestingly, it seems that the number of exposures to reach food acceptance is age-dependent (Cooke, 2007; Keller, 2014). For infants, a very few numbers of exposures can importantly enhance acceptance and clear effects might be seen even after a single exposure (Birch, Gunder, Grimm-Tomas, & Laing, 1998; Sullivan & Birch, 1990). By contrast, for preschoolers, studies suggest that 8 to 15 exposures are generally needed to change attitudes toward an exposed food (Cooke, 2007; Wardle et al., 2003). Finally, neophobia can be overcome with a single exposure in children older than 9-year-old (Loewen & Pliner, 1999). Future investigations comparing the effectiveness of ME across a wide age range are thus needed to identify potential sensitive periods, during which children are more likely to be sensitive to exposure interventions.

It is plausible that, the influence of age on the number of exposures needed to enhance positive attitudes towards new foods may be mediated by food rejections appearing in the toddler age (Keller, 2014). Recently, several studies pointed out that exposure interventions may not be efficient for highly neophobic and picky children (De Wild, De Graaf, & Jager 2016; Zeinstra, Kooijman, & Kremer, 2016). Such children can require until 27 exposures before accepting to taste a new food (William, Rizzo, & Riegel, 2008). Baseline level of food rejections should then be measured in exposure interventions to identify possible interactions with age.

2-3-Initial status of the exposed food

Mere exposure is thought to be more efficient with stimuli which are initially new or disliked for the subject, in contrast with initially familiar or liked stimuli (Lakkakula et al., 2010; Mennella & Beauchamp, 1999; Zajonc, 1698). For instance, Mennella and Beauchamp (1999) found that breastfed infants ate less of carrot-flavored cereals, if their mother consumed, for a week before, carrot juice instead of water. This counterproductive effect on already liked and familiar food items could be explained by sensory-specific satiation (i.e., the reduction of a food's hedonic value after repeated consumption; Rolls & Rolls, 1997). Some studies have nevertheless shown that, this counterproductive effect probably can be overcome by introducing a delay between the different exposure sessions, or a delay between the intervention sessions and later testing (e.g., a week delay after an initial eight-exposure intervention; Sullivan & Birch, 1990).

2-4-Is there a generalization to unexposed food stimuli?

There is to date no consensus regarding whether exposure to a food target can generalize to other food stimuli (Olsen, Ritz, Kraaij, & Møller, 2012). In some studies, it was observed that changes were restricted to the target food (Mennella, Nicklaus, Jagolino, & Yourshaw, 2008; Sullivan & Birch, 1990). For instance, Mennella and colleagues (2008) found that repeated exposure to pureed potatoes did not enhance acceptance of pureed carrots. However, transfer effects to other foods belonging to the same category than the target, or similar in form or substance, were observed in other studies (Birch et al., 1998; Tuorila, Meiselman, Bell, Cardello, & Johnson, 1994). For instance, Birch and colleagues (1998) found that repeated exposure to a preparation of banana enhanced intake of the same preparation, but also intake of another preparation of banana (same basic level category), as well as intake of pears (same super-ordinate category). However, it did not enhance intake of peas.

2-5-Explaining the variability across studies

Given the range of factors that can influence the success of repeated exposure (age, food rejection dispositions, number of exposures, status of the food, etc.), comparisons between interventions is of interest to identify those of greatest benefit. Nevertheless, comparison between exposure studies can prove difficult because a wide variety of outcome measures are used to assess efficacy and possible generalization. Outcome measures can involve measures of trait neophobia (e.g., Laureati, Bergamaschi & Pagliarini, 2014), willingness to try exposed foods (Wardle et al., 2003), food consumption in grams (Olsen et al., 2012), etc. Moreover, a variety of preparation methods have been used across studies, such as the use of raw vegetables (Wardle et al., 2003) or cooked vegetables (Caton et al., 2013; Remy et al., 2013). Finally, many exposure studies have failed to adopt an appropriate control group against which to compare the intervention group’s changes in food attitudes (Appleton et al., 2016; Dazeley et al. 2012). It is important that control groups are closely matched to experimental groups in terms of demographics, but also in terms of the food tested at baseline and post-test (equivalence in familiarity, liking, energy density, food category, etc.).

3. Mere visual exposure

Because neophobic reactions result in foods being rejected on mere sight (Cashdan, 1998; Dovey, Staples, Gibson, & Halford 2008; Lafraire, Rioux, Giboreau, & Picard, 2016), it is reasonable to suppose that *visual* exposure could be more efficient to reduce food rejections than *taste* exposure. Indeed, according to some authors, a child will taste a food only if it visually matches him/her prototypical food representations in mind (Brown, 2010; Dovey et al., 2008; Lafraire et al., 2016; see chapter 2). Additionally, while after weaning infants are normally familiarized with the taste of several vegetables (through pureed baby foods), they often are not familiarized with the visual aspect of the whole vegetables.

Furthermore, interventions seeking to enhance positive attitudes towards fruits and vegetables through taste exposure also increase the visual familiarity of the target. In studies that offer children repeated taste exposures, the food is both seen and tasted at each session, and it is difficult to isolate the effect of taste exposure alone (Dazeley et al., 2012; Heath, Houston-Price, & Kennedy, 2011). It is therefore plausible that the effectiveness of taste exposure interventions is partly due to a greater visual familiarity with the target food (Dazeley et al., 2012).

From a practical point of view, it could also be more effortless for caregivers to provide visual exposures to food (e.g., through picture books), especially if it occurs outside mealtimes (that carry the stress associated with ensuring the child is consuming a healthy diet; Dazeley & Houston-Price, 2015). In practice, taste exposure strategies may have limited efficacy, since several studies revealed that 8 to 15 taste exposures to a new food may be need for its successful acceptance (Wardle et al., 2003). This is a number greater than most parents are willing or able to provide (Carruth, Ziegler, Gordon, & Barr, 2004).

Very few ME studies have investigated whether the stimulus should be presented in the modality in which a changed attitude is desired. One exception is the seminal study by Birch and colleagues (1987) presented above, where the authors concluded that visual exposure alone had no positive effect on taste preferences. Nevertheless, it could be argued that visual exposure would not likely directly influence taste preferences but influence instead willingness to taste exposed foods (Houston-price, Butler, & Shiba, 2009).

There is in fact an encouraging body of evidence to support research into the impact of visual exposure on children food rejections (Dazeley et al., 2012; De Droog, Buijzen, & Valkenburg, 2014; De Droog, Van Dee, Govers, & Buijzen, 2017; Heath, et al., 2011; Heath, Houston-Price, & Kennedy, 2014; Houston-Price et al., 2009; Osborne & Forestell, 2012). For example, Heath and colleagues (2014) and De Droog and colleagues (2014) provided 2-to 6-year-old children with picture books about leeks and carrots respectively. They showed that toddlers consumed more of the vegetable they had seen in their picture book, compared to a matched control vegetable. Importantly, Heath and colleagues (2014) found similar changes in vegetable acceptance for highly neophobic children and their counterparts. This suggests that visual exposure might be employed successfully with children for whom taste exposure has been showed to be less efficient (De Wild et al., 2016; William et al., 2008; Zeinstra et al. 2016). Furthermore, Osborne and Forestell (2012), one of the few researchers who directly compared visual and taste exposure since Birch and colleagues (1987), found that visual exposure was as efficient as taste exposure to enhance willingness to taste new fruits in 4-to 8-year-old children.

The potential for visual exposure to enhance children's willingness to taste new foods therefore deserves further exploration, especially to investigate whether it produces long term effects. Indeed, there is a dearth of research evidence supporting long term changes in children's diets after taking part in exposure interventions (Appelton et al., 206; Evans et al., 2012; Knai et al., 2006). Moreover, changes in consumption are often more substantive for fruits than for vegetables (Appleton et al., 2016; Evans et al., 2012).

4. What are the mechanisms to explain the mere exposure effect?

4-1- The learned safety hypothesis

Surprisingly, while a large body of research has investigated the potential effect of exposure, the widely accepted mechanistic explanation remains elusive. One of the mechanism by which exposure is assumed to trigger a positive attitude toward a stimulus and overcome food rejection is thought to be "learned safety" (Kalat & Rozin, 1973; Zajonc, 2001). According to the learned safety hypothesis, food exposure removes our natural fear of new stimuli through a process of conditioning (Cooke, 2007). Repeated ingestion of a new food without negative consequences will lead to increase acceptance of this food, because children are more comfortable eating foods when they can anticipate the consequences of ingestion (Pliner & Hobden, 1992).
However, the recent evidence that mere visual exposure could also enhance the acceptance of new foods cast doubt on the learned safety hypothesis, at least to explain entirely the positive effect of exposure. Rejections usually occur at the mere sight of the food (Dovey et al., 2008)

and visual cues appear to be more important for children than for adults in the decision to try a new food (Dovey, Aldridge, Dignan, Staples, Gibson, & Halford, 2012). Therefore, there are valid grounds for assuming that food visual appearances might play a more significant role, compared to the absence of post-ingestion consequences in a child's decision to consume a new food item (Heath et al., 2011).

4-2-A cognitive approach to the mere exposure effect

Bornstein and D'Agostino (1994) offered an alternative explanation which embodies a cognitive approach to the mere exposure effect, reconciling with the positive results found with visual exposure. By increasing the level of experience an individual has with any stimulus, repeated exposure increases the ease and speed with which this stimulus is processed and categorized, leading to a positive attitude toward this stimulus (Bornstein & D'Agostino, 1994; Seamon, Williams, Kim, Crowley, Langer, Orne, & Wishengrad, 1995). When a food is first presented to a child, it is organized into categories relating to its characteristics (Murphy, 2002; Vauclair, 2004; see also Lafraire, Rioux, Roque, Giboreau, & Picard, 2016). Knowledge gained through this first encounter allows for easier and faster categorization when subsequently presented with the same or a similar food item (Aldridge, Dovey, & Halford, 2009). According to this cognitive approach, the ease of categorization of a given food should lead of the reduction of food rejection behaviors. Future investigations are needed to directly test this assumption.

It is important to note that, within this cognitive approach, whether positive effects are restricted to the exposed stimulus or, are generalizable to other instances of the category of the exposed stimulus remains to be seen. Borstein and D'Agostino (1994) originally proposed that exposure to a stimulus facilitated subsequent encoding processes and categorization only for that given stimulus. On the other hand, Lafraire, Rioux, Giboreau and colleagues (2016) proposed that exposure rather enriches the content of the prototype's feature list of the category at hand and then, facilitates subsequent categorization for other instances of the category of the exposed stimulus (chapter 2). This is also in line with the role of experience (or exposure) in inductive reasoning, which suggests that the more sophisticated children's knowledge is in a given domain, the more likely children are to engage in category-based induction within this domain (see chapter 2). Further studies are then needed to better grasp the mechanisms that underpin the effectiveness of mere exposure interventions and the impact of visual exposure on food category representations.

5. “Simple” or “diverse” mere exposure?

In most of studies investigating the effect of mere taste exposure, children were exposed to the same mode of presentation of a given food across exposure sessions (e.g., Olsen et al., 2012; Remy et al., 2013). For instance, Remy and colleagues (2013) proposed for 10 days the same preparation of artichoke puree. By contrast, most studies investigating the effect of visual exposure used diverse presentations of the target foods (Heath et al., 2014; Houston-Price et al., 2009; Osborne & Forestell, 2012), making the comparison between these two designs rather difficult. Heath and colleagues (2014), for example, used picture books with five different pictures of the target food (a picture of the food on its plant, a picture of the food cut in the plate, etc.).

In a recent study, Houston-Price, Burton, Hickinson, Inett, Moore, Salmon and Shiba (2009) directly compared these two kinds of designs. They exposed toddlers for two weeks with either picture books containing five *identical* pictures of a given fruit (e.g., an apple), or with picture books containing five *different* pictures of the same fruit (e.g., an apple on a tree, an apple cut in a plate etc.). Results revealed that offering children different modes of presentation of an exposed food led to greater visual interest for this food. The authors hypothesized that toddlers’ more positive attitudes toward the fruit after the “diverse” exposure intervention were driven by experiences that had allowed them to furnish an elaborate representation in mind of the exposed food. This view is consistent with Lafraire, Rioux, Giboreau and colleagues’ hypothesis (2016), that within the cognitive approach, exposure enriches the content of the category at hand.

Nevertheless, the study conducted by Houston-Price, Burton and colleagues (2009) only measured visual interest (through duration of looking time) and not food consumption. Future studies comparing simple versus diverse visual exposure are then needed to investigate whether this greater visual interest found with diverse exposure will result to greater acceptance and consumption of the exposed food.

6. Conclusion

The mere exposure to one instance of a given food stimulus is sufficient to trigger a more positive attitude toward a subsequent instance of that stimulus (Zajonc, 1968) and ME interventions seem to be as effective as FFL/FNL interventions. Therefore, ME appears to be the simplest choice to enhance positive attitude towards fruits and vegetables and to decrease food rejections (Appleton et al., 2016; Bouhlal et al., 2014).

There is a rising body of evidence in favor of the positive effect of mere visual exposure alone, suggesting that food pictures might help parents to deal with some of the difficulties associated with the introduction of new foods. Nonetheless, further studies are needed to better grasp the mechanisms that underpin the effectiveness of mere visual exposure interventions and the impact of visual exposure on food representations.

Chapter 4. Problematic and theoretical hypotheses

Food rejections of young children can have negative consequences on health, notably because they mostly concern fruits and vegetables. It is essential to promote the adoption of healthier eating behaviors among young children, and only a better understanding of the mechanisms underlying food rejections will allow designing effective interventions in ecological settings. To address this goal, and based on the literature review presented in the three previous chapters, four main objectives were delimitated for the present thesis, presented successively in the following chapter. For each objective, the specific research hypotheses are detailed as well as the methodologies employed to test them.

1. Definition and measure assessment of food neophobia and pickiness (Part B)

1-1- Objectives

There is a need for further development of tools to measure both food neophobia and pickiness, since recent reviews have pointed out that most existing scales are not entirely psychometrically sound. This is a major gap in the field of childhood eating behaviors assessment, which would be well worth filling. These new tools should focus on children as young as 2 years of age because this is the onset of food rejections (chapter 1).

Additionally, the current literature lacks decisive empirical evidence in favor of an independence or a correlation between these two components of food rejections. This is arguably explained because there is still some confusion surrounding the concept of pickiness (chapter 1).
It would be therefore useful to conduct psychometric studies to develop and validate a scale of food rejections, including items relative to food neophobia and pickiness. Specifically, investigations of the factorial structure of such a scale would help to disambiguate the concept of pickiness and provide an insight into the currently obscure relationship between food neophobia and pickiness.

The first objective of the present thesis is a methodological one: to develop and validate a hetero-assessment scale to measure both food neophobia and pickiness for French children as young as 2-year-old.

The second objective of the present thesis is to disambiguate the concept of pickiness and to provide an insight into the relationship between food neophobia and pickiness.

1-2- Research hypotheses

First, what appears as the rejection of foods that are familiar to children (understood as pickiness) might be in fact the rejection of foods previously accepted, but perceived as new by the child because of some changes in the recipe (chapter 1). Rejections occurring after the tasting step are primarily texture rejection, because texture can only be completely determined within the child's mouth, and certain textures inform about the hazardousness of a food (chapter 1).

The first hypothesized of the present thesis is that, what appears as two distinct constructs (pickiness as rejection of familiar foods and some textures, and neophobia as rejection of new foods) capture a same kind of fear for *new and potentially toxic foods*; changes in shapes, textures or colors across recipes could make an already tasted vegetable appearing as a new vegetable for a child.

1-3- Research methodology

To achieve the above-mentioned objectives, a first experiment was conducted (chapter 5, Exp. 1, article 1) where a new scale for the assessment of food neophobia and pickiness, for French children aged 2-to 6-year-old was developed and validated. A first version of the scale was tested on a first sample of caregivers, who responded for their children, to select the relevant items, especially for food pickiness. A factor analysis was then performed on a second shortened version of the scale, with a second (new) sample of caregivers, to provide an insight into the relationship between food neophobia and pickiness.

2. Bringing knowledge to the table: the development of food categorization and rejections in young children (Part C)

2-1- Objectives

Although predictors for food neophobia and pickiness have been extensively investigated, few studies have yet linked cognitive capabilities and food rejections. This is quite surprising considering that food rejections peak around 2-to 3-years, precisely when improvements appear in the child's food categorization system (chapter 2). This concomitance may not be a sheer coincidence and calls for further investigation.

The third objective of the present thesis is to directly investigate the relationship between categorization development in young children (2-to 6-year-old) and their food neophobia and pickiness. Both categorization development *per se* and category-based induction development were considered because the hallmarks of a mature categorization system are the abilities:

(i) To recognize and sort into categories the different stimuli in our environment and;

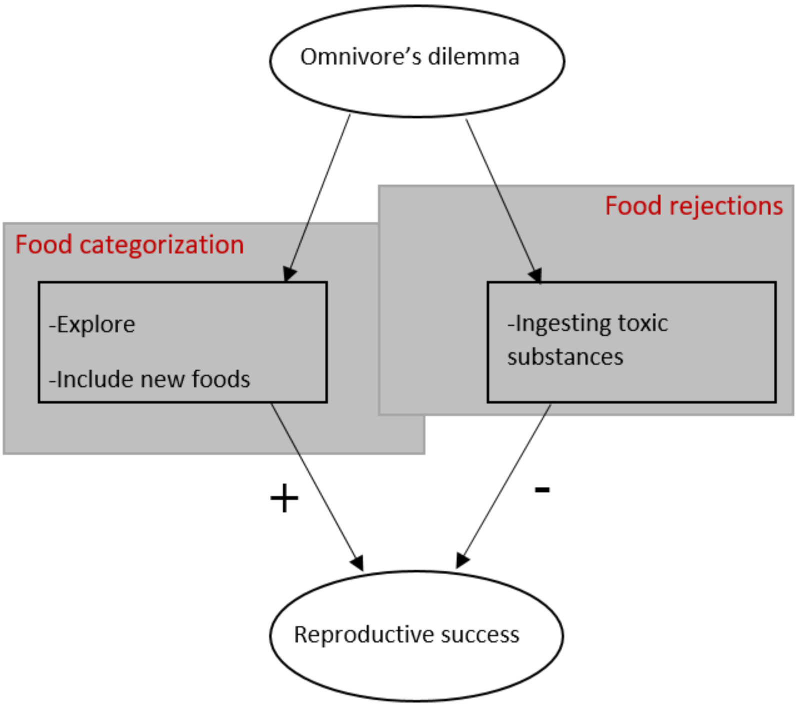
(ii) To make predictions about new items, based on the knowledge of the category of these new items.

2-2- Research hypotheses

Food neophobia is thought to be an adaptive solution to the omnivore dilemma (chapter 1). Indeed, after weaning, infants need to include new food resources to have a diverse diet to ensure healthy development. However, this search for variety is a highly risky endeavor, as new substances may be toxic and deathful; a natural reluctance to reject new substances is an efficient system to avoid ingesting toxic elements. On the other hand, a food categorization system, appearing to be domain-specific, allowing for a food/nonfood distinction, discrimination between different food items, and inferences of edibility, or other relevant properties for consumption, enables efficient sampling of food resources and enrichment of children's food repertoire (chapter 2).

Therefore, a protective system against the ingestion of potentially dangerous substances (food neophobia and pickiness) and a domain-specific cognitive module, allowing categorization and inductive reasoning about food (food categorization and induction) might be the two complementary facets of the adaptive solution to the omnivorous dilemma (see Fig.7).

Figure 7. Food rejections and food categorization processes as plausible adaptive solution to the omnivorous dilemma.

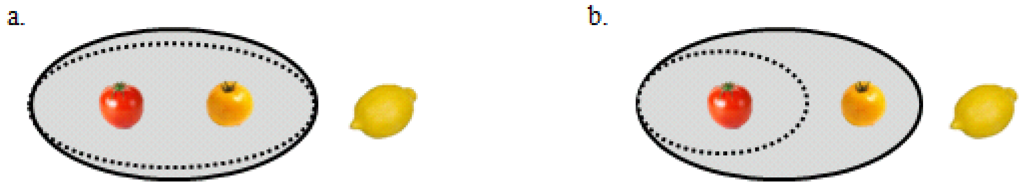


Actually, there is a concomitance of the development of the two phenomena. The sensitive period for food rejection starts at around 2 years of age, when toddlers begin to reason about food, possibly outside parental guidance, once they are mobile enough to reach for objects available in their proximal environment (chapter 1). That is also at this point that an efficient food categorization and induction system is assumed to take place within the child's cognitive system (chapter 2).

The second hypothesis of the present thesis is that food rejections are closely intertwined with the development of food categories and that food rejections are the behavioral consequences of an immature food categorization system. Immature food categories are likely characterized by poorer informational content, which lead to a low probability of an acceptable similarity between a presented food item and the prototype of the category. The immaturity of the food categorization system is then characterized by a proper domain bigger than its actual domain (see Fig 8b). When a presented food item is not

subsumed under a certain category (a miss), because it has not an acceptable similarity with its prototype, and property of the presented food cannot then be inferred (such as the property *edible*), rejection will occur.

Figure 8: Example of a mature and an immature food category.



Note. (a) Mature tomato category. (b) Immature tomato category. The continuous circle represents the proper domain of the tomato category: all the tomatoes in our environment that should be accepted in the tomato category. The dotted circle represents the actual domain of the tomato category, which is only the tomatoes that have an acceptable similarity with the prototype. Citrus fruits are normally excluded from the tomato category and are not in the proper domain of this category.

If food rejection is a consequence of an immature food categorization system and food categorization is mainly color-dependent (chapter 2), then some food colors should trigger food rejection. Macario's experiment (1991) supports this idea (chapter 2).

By 2 years of age, a food's color is considered an invariant aspect of its identity (Mura Paroche, Caton, Vereijken, Weenen & Houston-Price, 2017). It is possible then that color is important, mainly because it conveys information about the typicality of a given food exemplar contrary to shape or texture, which vary more across recipes and preparations. Atypical items of a given category are frequently excluded from that category (chapter 2), and the atypically colored photographs in Macario's experiments (1991), were indeed excluded from the human food category.

The third hypothesis of the present thesis is that food categorization is mainly color-dependent, but color is not only important *per se*. It also conveys information about the typicality of a given food exemplar.

2-3- Research methodology

To investigate these two hypotheses, in a second experiment a categorization task (chapter 6, Exp. 2, article 2, appendix 1), and in a third experiment a category-based induction task (chapter 7, Exp. 3, article 3, appendices 2-5) were conducted with children aged 2-to 6-year-old. Both experiments involved the use of fruit and vegetable categories. For each fruits and vegetables, typically colored and atypically colored exemplars were included in the experimental stimuli. These categories were chosen because they are likely to be rejected by children in this age range. Accuracy measures were recorded for both these tasks (categorization task and category-based induction task), to capture the maturity of the food categorization system, and related with food rejection scores (measured through our developed questionnaire).

3. Designing a visual exposure intervention to overcome food rejections (Part D)

3-1- Objectives

At a practical level, it is important to understand the relationships between food behaviors and cognitive development in the food domain to design more efficient education programs aiming at promoting healthier eating behaviors among children. Indeed, reviews pointed out that few existing interventions are efficient enough to increase vegetable consumption in children (chapter 3). While a large body of research has investigated food consumption in children, the majority of interventions have used levers on food behavior such as mere taste exposure without successfully explaining the mechanisms responsible for these potential effects (chapter 3).

The fourth objective of the present thesis is therefore to design an intervention, based on visual exposure and exploiting the empirical evidence on the relationship between food categorization and food rejections, to positively influence children food rejections.

3-2- Research hypotheses

Mere exposure interventions appear to be the simplest choice to enhance positive attitude towards fruits and vegetables and to decrease food rejections (chapter 3). Previous research on ME has been mainly focus on taste exposure. Yet, there are valid grounds for assuming that, because neophobic reactions occur at the mere sight of the food, appearances might play a more significant role, compared to the absence of post-ingestion consequences, in a child's decision to consume a new food (chapter 3).

An alternative mechanism to the learned safety hypothesis has been proposed: by increasing the level of experience and knowledge an individual has with any stimulus, repeated exposure increases the ease with which this stimulus is categorized, triggering a feeling of familiarity, (chapter 3). Additionally, diverse visual exposure seems to be more efficient, than simple visual exposure, as it would allow furnishing a more elaborate representation in mind of the exposed food (chapter 3). Future studies are nevertheless needed to investigate whether this greater interest will result to greater acceptance of the exposed food.

The fourth hypothesis of the present thesis is that visual exposure is efficient to enhance food acceptance because it facilitates categorization. This ease will be enhanced with diverse visual exposure.

Non-exposed children would have a poorer representation, of the tomato category (for instance), tied to a specific perceptual property. By contrast, exposed children would have a richer representation not tied to a perceptual property. For these latter children, tomatoes could be red but also yellow and used in pasta. Because the more sophisticated a child's knowledge is, the more likely a child is to engage in category-based induction and may disregard perceptual similarities, exposed children will generalize knowledge based on category membership and not by perceptual similarity.

3-3- Research methodology

To investigate this hypothesis, in a fourth experiment (chapter 8, Exp. 4, article 4, appendices 6-9) a visual exposure intervention was proposed in school canteens with pictures of vegetables set on tables in cafeterias. Both simple and diverse exposure were tested to directly investigate the potential benefit of the latter exposure. In the diverse exposure, the vegetables varied in term of color, because color is a perceptual cue with high predictive value in the food domain (chapter 2). In this case children would learn that color similarity is not predictive enough and should be disregarded in favor of labels, when making predictions and consumption choice about foods.

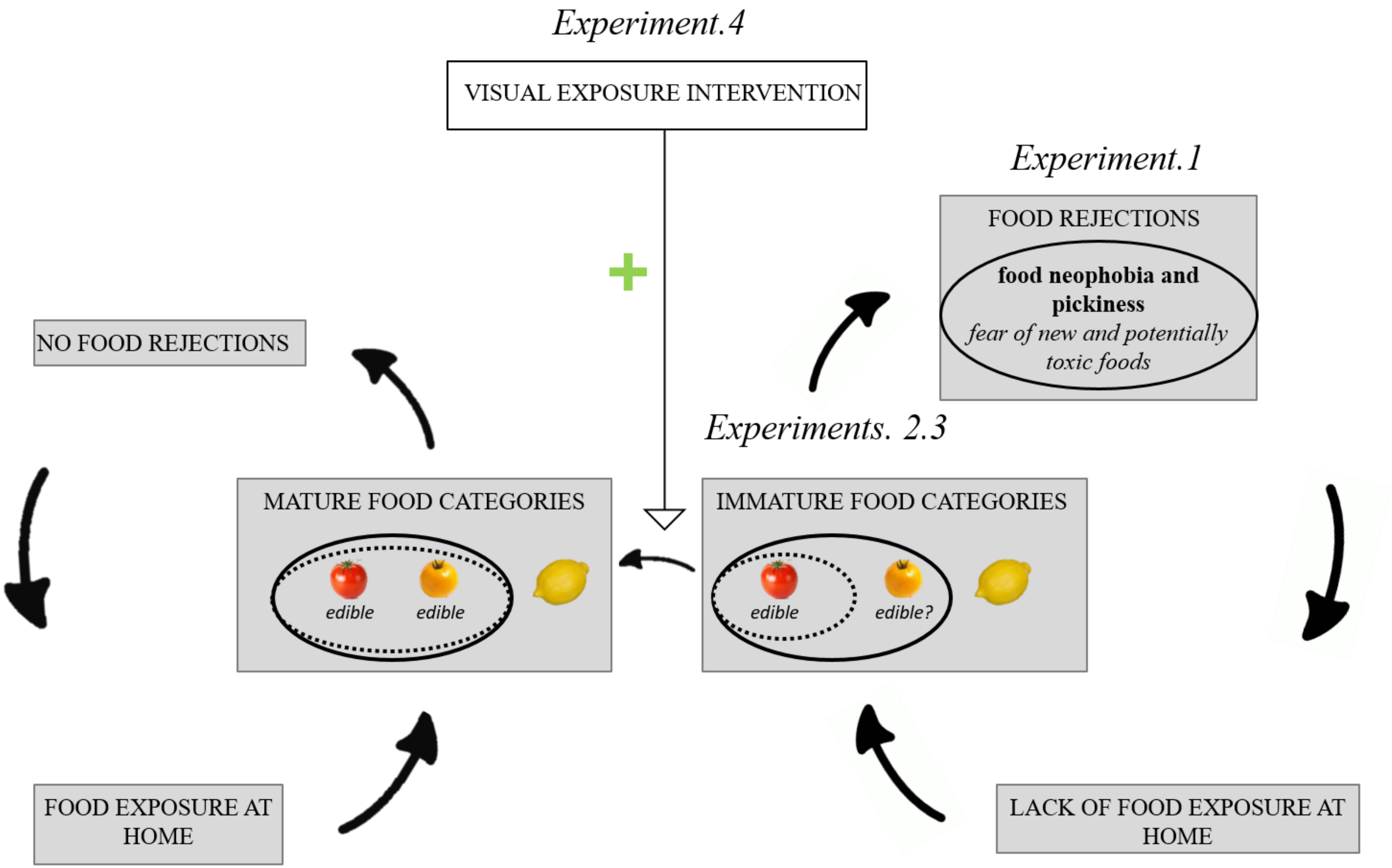
4. Conclusion

The different hypotheses of the present thesis are summarized Fig 9. Their investigation is realized through 4 experiments, presented in the order they were introduced, in chapter 5, 6, 7 and 8 of this manuscript.

Neophobia and pickiness, because they are probably not theoretically distinct (hypothesis tested in chapter 5, Exp. 1, see Fig. 9), serve the same protective function: to prevent children from ingesting potential poisonous food items. They may be both seen as the result of an immature food categorization system (hypothesis tested in chapter 6 and 7, Exp.2 and Exp. 3, see Fig. 9). Food rejections exhibited by children that have the disposition to be neophobic and picky, may in turn discourage caregivers to present fruits and vegetables to their children because of reluctance to waste food. This lack of exposure to fruits and vegetables leads to fewer learning opportunities which, in turn, may impact negatively on food categorization and inductive reasoning (see Fig. 9).

A promising way to break this circle would be to enhance conceptual knowledge with visual exposure (tested in chapter 8, Exp.4, see Fig. 9). Food pictures might help parents to deal with some of the difficulties associated with the introduction of new vegetables, or new preparation of familiar vegetables.

Figure 9: Putative relation between food categories, food rejections and visual exposure.



PART B. DEFINITION AND MEASURE ASSESSMENT OF FOOD NEOPHOBIA AND PICKINESS

Chapter 5. Development and validation of a new scale to assess food neophobia and pickiness among 2- to 7-year-old French children

This chapter focuses on the development and validation of a questionnaire to assess both food neophobia and pickiness in French children as young as 2 years of age.

Within this young population, only a hetero-assessment scale can be used. Indeed, toddlers have difficulty responding on a several-point agreement scale (Guignard, 2000; Laureati, Bergamaschi, & Pagliarini, 2015). Therefore, caregivers (often mothers) respond in behalf of their children.

Nevertheless, it is important to have in mind that hetero-assessment scales raise several difficulties, and that they are only approximation of children food rejection dispositions. Indeed, there are potential social desirability biases (i.e., parents may present a better image of their children or themselves), or parents may sometimes project their own behaviors onto those of their children (Mata, Scheibehenne, & Todd, 2008). In fact, caregivers' reports of their children's neophobia only moderately correlate with children's report of their own neophobia (Pliner, 1994).

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Original article

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

L'échelle de rejets alimentaires pour enfant : développement et validation d'une nouvelle échelle pour mesurer la néophobie et la sélectivité alimentaire chez les jeunes enfants français de 2 à 7 ans

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ABSTRACT

Introduction. – The two strongest obstacles to extend children's consumption of fruit and vegetables are food neophobia and pickiness, assumed to be the main kinds of food rejection in children. Accordingly, psychometric tools that provide a clear assessment of these kinds of food rejections are greatly needed.
Objective. – To design and validate a new scale for the assessment of food neophobia and pickiness, thus filling a major gap in the psychometric assessment of food rejection by French children.
Method. – We concentrated on French children aged 2–7 years, as no such scale exists for this young population, and on the two known dimensions of food rejection, namely food neophobia and pickiness, as the nature of the relationship between them is still unclear. The scale was tested on two samples ($N_1 = 168$; $N_2 = 256$) of caregivers who responded for their children. Additionally, a food choice task was administered to 17 children to check the scale's predictive validity.
Results. – The resulting scale, called the Child Food Rejection Scale (CFRS), included six items relating to food neophobia and five items relating to pickiness. A factor analysis confirmed the two-dimensional structure of the scale. Internal consistency, test–retest reliability, and convergent and discriminant validity were all satisfactory. Moreover, results from the food choice task showed that scores on the CFRS accurately predicted children's attitudes toward new and familiar foods.
Conclusion. – Taken together, these findings suggest that the CFRS, a short and easy-to-administer scale, represents a valuable tool for studying food rejection tendencies in French children.
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RÉSUMÉ

Introduction. – La néophobie et la sélectivité alimentaire, responsables d'une réduction de la variété du régime alimentaire, sont présentées comme les deux facteurs principaux des rejets alimentaires chez les enfants. Par conséquent, afin de pouvoir étudier ces formes de rejets, il est important de disposer d'outils robustes permettant de les mesurer.
Objectif. – Développer et valider une nouvelle échelle pour évaluer la néophobie et la sélectivité alimentaire, comblant ainsi une lacune importante dans l'évaluation psychométrique des rejets alimentaires chez les enfants français.
Méthode. – Nous nous sommes concentrés sur les enfants français âgés de 2 à 7 ans, comme il n'existe pas d'échelle pour cette jeune population, et sur les deux dimensions connues des rejets alimentaires, à savoir la néophobie et la sélectivité alimentaire, comme la nature de leur relation est encore inconnue.

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L'échelle a été testée sur deux échantillons ($n1 = 168$; $n2 = 256$) de parents qui ont répondu pour leurs enfants. De plus, une tâche de choix d'aliments a été administrée à 17 enfants pour vérifier la validité prédictive de l'échelle.

Résultats. – L'échelle finale, appelée *Échelle de rejets alimentaires pour enfant* (CFRS), comprend six questions relatives à la néophobie alimentaire et cinq relatives à la sélectivité. Une analyse factorielle a confirmé la structure bidimensionnelle de l'échelle. La cohérence interne, la fiabilité temporelle et la validité convergente et discriminante sont satisfaisantes. De plus, les résultats de la tâche de choix ont montré que les scores à la CFRS prédisent avec précision les attitudes des enfants à l'égard des aliments nouveaux et familiers.

Conclusion. – Les résultats suggèrent que la CFRS, une échelle courte et facile à administrer, représente un outil adapté pour l'étude des rejets alimentaires chez les jeunes enfants français.

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1. Introduction

Despite increasing wealth and purchasing power in the Western world, there is an alarming deterioration in dietary habits, including the increased consumption of foods rich in saturated fatty acids at the expense of foods rich in fibers, vitamins and minerals, such as fruit and vegetables (Carruth, Skinner, Houck, Moran, Coletta, & Ott, 1998; Cashdan, 1998; Jacobi, Agras, Bryson, & Hammer, 2003). Indeed there is a wide gap between recommended intake and actual consumption of fruit and vegetables (Cockroft, Durkin, Masding, & Cade, 2005; WHO, 2003). The two strongest obstacles to extend children's intake of fruit and vegetables are *food neophobia* and *pickiness*, assumed to be the main kinds of food rejection in children (Birch & Fisher, 1998; Dovey, Staples, Gibson, & Halford, 2008; Falciglia, Couch, Gribble, Pabst, & Frank, 2000). Accordingly, psychometric tools that provide a clear assessment of food neophobia and pickiness are greatly needed as they are important to the study of childhood food habits and the effectiveness of interventions or programs designed to expand children's intake of fruit and vegetables. In the present paper, we describe how we developed and validated a new and much needed scale to assess the food neophobia and pickiness dimensions of food rejection in young children.

Food neophobia is defined as a fear of new food (Pliner & Hobden, 1992), and appears as children become mobile, but there is a contention in the literature as to whether it increases thereafter (Birch, McPhee, Soba, Pirok, & Steinberg, 1987; Cashdan, 1994; Harper & Sanders, 1975) or remains stable during early childhood (Addessi, Galloway, Visalberghi, & Birch, 2005; Cooke, Wardle, & Gibson, 2003; Koivisto & Sjöden, 1996). In 1992, Pliner and Hobden (1992) designed the Food Neophobia Scale (FNS), which ask adult to specify the extent to which they approve or not ten declarations about eating practices, like "If I don't know what is in a food, I won't try it". Originally devised to measure adults' neophobia, the FNS was subsequently adapted to assess children's neophobia (Children Food Neophobia Scale [CFNS]; Pliner, 1994). Both of Pliner's scales have since been widely used to measure food neophobia, adapted and translated into several languages, including French (Adapted Food Neophobia Scale; Reverdy, Chesnel, Schlich, Köster, & Lange, 2008) and Italian (Italian Children Food Neophobia Scale; Laureati, Bergamaschi, & Pagliarini, 2015).

Food pickiness is characterized as a rejection of a certain amount of familiar and new foods to children (Birch, Johnson, Andresen, & Peters, 1991; Galloway, Fiorito, Lee, & Birch, 2005; Smith, Roux, Naidoo, & Venter, 2005; Taylor, Wernimont, Northstone, & Emett, 2015). Pickiness also includes the intake of inadequate quantities of food (Rydell, Dahl, & Sundelin, 1995), or may relate to the rejection of certain food textures (Smith et al., 2005). A contention concerns the developmental path of pickiness (Taylor et al., 2015). According to Dubois, Farmer, Girard, Peterson, and Tatone-Tokuda (2007) the prevalence of pickiness remains relatively stable during early childhood (2.5–4.5 years), whereas a recent longitudinal study by Mascola, Bryson, and Agras (2010) showed that the highest prevalence of pickiness arises in toddlerhood, and subsequently decreases to very low levels by the age of 6 years. A further contention exists concerning the relationship between food pickiness and neophobia. In their review, Dovey et al. (2008) supposed that the two constructs are behaviorally distinct, as dissimilar factors foresee their extend and manifestation. However, other researchers have argued that these two kind of food rejections are undoubtedly linked (Potts & Wardle, 1998; Raudenbush, van der Klaauw, & Frank, 1995) or even indistinguishable (Wardle, Guthrie, Sanderson, & Ropoport, 2001). Up to now, a controversy exists concerning the relationship between food pickiness and neophobia, which arguably can be partly explained because there is clearly still some confusion surrounding the very concept of pickiness (Potts & Wardle, 1998; Taylor et al., 2015). While neophobia is usually assessed through Pliner's scales (Pliner & Hobden, 1992; Pliner, 1994) or adapted versions, there is no such widely recognized scale for pickiness measurement. It has usually been assessed through various tools such as scales on eating practices that include subscales for pickiness, food neophobia, low enjoyment when eating, and so forth. Notable questionnaires include the Children's Eating Behavior Questionnaire (CEBQ see Wardle et al., 2001; Tharner et al., 2014), and Children's Eating Difficulties Questionnaire (CEDQ see Rigal, Chabanet, Issanchou, & Monnery-Patris, 2012). Other researchers have measured pickiness by merely questioning caregivers if their children are picky (Carruth, Ziegler, Gordon, & Barr, 2004; Jacobi et al., 2003; Jacobi, Schmitz, & Agras, 2008).

In a recent review of methods to assess preschool children's eating behavior, De Lauzon-Guillain et al. (2012) pointed out that most of existing scales measuring children's food neophobia and/or pickiness are not entirely psychometrically sound. Indeed only the French Questionnaire pour Enfant de Neophobie Alimentaire (QENA, Rubio, Rigal, Boireau-Ducept, Mallet & Meyer, 2008) and the CEBQ (Wardle et al., 2001) achieved all validity and reliability criterion (other questionnaires such as the widely used FNS and CFNS failed to validate construct validity and/or temporal reliability). However, the QENA is a self-assessment questionnaire designed to measure neophobia for at least 5 years old children, while it would be of interest to measure neophobia for 2 years old children because it is the onset of food rejections. Additionally, the CEBQ does not differentiate between food neophobia and pickiness, while recent reviews and researches have proposed that they are two latent variables (Dovey et al., 2008; Galloway, Lee, & Birch, 2003; Rigal et al., 2012). Therefore there is a need for further development of tools to measure both neophobia and pickiness as two possible dimensions of food rejections in critical period (2–7 years old) in French toddlers.

In the present study, we adapted and validated a new scale for the assessment of food neophobia and pickiness, both thought to be dimensions of food rejection, in young French children. We concentrated on children aged 2–7 years, as no such scale exists for this young population. Moreover, contrary to previous scale measurement, we took special care to assess all aspects of pickiness behaviors and to measure all the properties that would be expected of any psychometric instrument, namely internal consistency, factor structure, discriminant and convergent validity, test–retest reliability, and construct validity (see, for example, De Lauzon-Guillain et al., 2012; Hinkin, 1995; Ritchey, Frank, Hursti, & Tuorila, 2003; Vallerand, 1989). Finally, we believed that designing and testing the validity of a scale that included items on food neophobia and items on pickiness would provide an insight into the (currently obscure) relationship between these two constructs, as well as the (currently opaque) nature of their developmental paths.

2. Preliminary experiment: item generation and selection

2.1. Method

2.1.1. Questionnaire design

Our main concern was to propose a short and easy-to-administer scale, all the while ensuring good content validity that is, capturing the two specific constructs (i.e., food neophobia and pickiness) without including any superfluous content. Developing a brief measure is an efficient mean of minimizing participants' fatigue and response biases (Hinkin, 1995). Our objective was to come up with a scale featuring a set of around 10 carefully selected items (i.e., items loading strongly on one of the two assumed dimensions). To this end, we adapted from existing scale and developed more items than necessary for the definitive questionnaire, so that we could reject any items that were potentially inaccurate, recurrent or indistinct, and yet retain an enough figure of items to ensure a reliable tool (Gehlbach & Brinkworth, 2011). To generate these items, we first reviewed the literature, in order to precisely define the two constructs under consideration and assess previous measures (Lafraire, Rioux, Giboreau, & Picard, 2016). We then extracted and adapted 18 items from existing scales that proved to accurately capture the two constructs and predict food rejection behaviors. All items regarding neophobia were adapted from the FNS (Pliner & Hobden, 1992) or the QENA (Rubio et al., 2008) as the first scale is widely used to assess neophobia and the second was proved to be perfectly psychometrically sound. All items regarding pickiness were adapted from the CEBQ (Wardle et al., 2001) and the CEDQ (Rigal et al., 2012) as the first scale is usually used to assess pickiness and the second is a French scale targeting under 5 years old children, thus adapted to the population of the study. Additionally we created 23 additional items based on the definitions of the two constructs. The majority of the additional items concerned pickiness. Indeed, as the review of the literature revealed, while neophobia is a rather well defined construct, there is clearly still some confusion surrounding the very concept of pickiness, and existing scales do not encompass every suspected aspect of this construct (such as the rejection of certain texture). We thus compiled 41 items in total: 20 items relating to food neophobia and 21 items relating to pickiness. We decided to avoid reverse-scored items as this has been shown to diminish scale reliability and possibly introduce systematic errors (Gehlbach & Brinkworth, 2011; Schriesheim & Hill, 1981). Hence, each of the 41 items was a positive sentence, such as "My child is constantly looking for familiar foods".

To verify that the items we had compiled and generated were clear and fully captured the two constructs, we tested the 41-item questionnaire for cognitive validity (Gehlbach & Brinkworth, 2011; Karabenick et al., 2007). To this end, a pilot study was run with a group of 10 women, either mothers or childminders, recruited from a nursery association in the French city of Lyons. These participants received the questionnaire at home and were asked to indicate whether or not they thought each item was clear and relevant to assess children food rejection behaviors on two separate 5-point Likert-like scales). Afterwards, a collective interview was held on the association's premises, and questions and comments about the items raised by participants were discussed. Additionally, the women were asked to indicate any other eating behaviors they could think of, displayed by children during mealtimes. Following this interview, six items were removed owing to vagueness and misunderstanding, and none were added, leaving a provisional 35-item questionnaire to be administered and psychometrically analyzed (see Appendix for the 35-item version of the questionnaire).

2.1.2. Participants and procedure

The 35-item questionnaire was administered online to 205 parents recruited on food blogs or social networks with no exclusion criteria, who each responded at the time of their convenience for their child aged between 2 and 7 years. None of them had been involved in the preliminary experiment. Parents who were not direct caregivers ($n = 11$) or who did not finish the poll ($n = 26$) were extracted from the study, leaving a first sample N_1 of 168 participants (138 mothers and 30 fathers). Caregivers rated each item according to their child's behavior (83 girls and 85 boys aged 23–84 months, mean age = 48 months, $SD = 16$) on a 5-point Likert-like scale (*Strongly disagree*, *Disagree*, *Neither agree nor disagree*, *Agree*, *Strongly agree*). This 5-point Likert-like scale was chosen so as to allow for sufficient variance among the participants (Gehlbach & Brinkworth, 2011; Lissitz & Green, 1975). We used verbal anchors, rather than numerical ones, because numbers can have implicit meanings (Gehlbach & Brinkworth, 2011). Each answer was then numerically coded (from *Strongly disagree* = 1 to *Strongly agree* = 5), with a high score indicating high food rejection (scores could range from 35 to 175). Participants were informed they will receive a booklet providing nutritional advice and tips for recipes after completion of the survey. This preliminary experiment was performed in adherence with the principles established by the declaration of Helsinki.

2.1.3. Data analysis

For each child, we calculated a food rejection score ranging from 35 to 175, based on the caregiver's answers. Preliminary analyses were ran on these scores to check the normality of the data distribution (Anscombe–Glynn kurtosis test). Then, the mean food rejection scores for each sex were measured and compared (Student's t test), and correlations between food rejection scores and children's age were assessed (Pearson correlation coefficient). Finally, we performed an iterative exploratory factor analysis using principal component analysis with promax rotation, to determine the number of dimensions of the scale and select the different items to include in the decisive scale. We set the alpha level at 0.05 for all statistical analyses. All statistical analyses were conducted using R 3.1.2 software, using the packages "psych" and "FactoMineR".

3. Results

3.1. Preliminary analysis

Food rejection scores ranged from 45 to 171 ($M = 97.6$, $SD = 27$). Checks for kurtosis showed that the food rejection scores were distributed normally ($z = 0.81$, $P = 0.41$, *ns*). Then analysis revealed that these scores were not influenced by the gender of either the caregiver ($t = 1.51$, $P = 0.13$, *ns*) or the child ($t = 0.71$, $P = 0.94$, *ns*). Data were therefore computed across these factors in subsequent

Table 1
Descriptive statistics and factor loadings from the exploratory factor analysis.

Item	Mean	*SD*	Factor 1	Factor 2
P3. Mon enfant refuse de manger certains aliments à cause de leurs textures *(My child refuses certain foods due to their texture)*	3.3	1.2	0.14	0.48
P4. Mon enfant fait le tri dans son assiette *(My child sorts his/her food on the plate)*	3.3	1.2	0.28	0.56
P5. Mon enfant rejette certains aliments après les avoir goûté *(My child rejects certain foods after tasting them)*	3.9	0.7	0.14	0.75
P6. Mon enfant peut manger un aliment aujourd'hui et le refuser demain *(My child can accept one food one day and refuse it the next day)*	3.4	1.3	0.24	0.89
P10. Mon enfant peut manger certains aliments en grandes quantités et d'autres pas du tout *(My child can eat some foods in large amounts and completely reject others)*	4.0	1.1	0.15	0.69
N1. Mon enfant recherche constamment des aliments familiers *(My child is constantly looking for familiar foods)*	3.2	1.2	0.79	0.05
N2. Mon enfant se méfie des aliments nouveaux *(My child is suspicious of new foods)*	3.2	1.2	0.78	0.05
N4. Mon enfant aime seulement la cuisine qu'il connaît *(My child only likes the familiar foods)*	2.6	1.2	0.83	0.07
N6. Mon enfant rejette un nouvel aliment avant même de l'avoir goûté *(My child rejects a novel food before even tasting it)*	3.0	1.3	0.73	0.10
N7. Mon enfant est angoissé à la vue d'un nouvel aliment *(My child gets upset at the sight of a novel food)*	2.0	1.1	0.90	0.20
N10. Mon enfant ne goûte pas un nouvel aliment si cet aliment est en contact avec un autre aliment qu'il n'aime pas *(My child won't try a novel food if it is touching another food he/she does not like)*	2.6	1.1	0.62	0.13

The criterion for loading was > 0.45. Items referring to neophobic behaviors are coded *N* and items referring to picky behaviors are coded *P*.

analyses. Moreover, prior the analysis, we checked the items for sufficient item variability. The majority of items had medium means (between 2 and 4 on the 5-point Likert-like scale), signifying that there were no ceiling and floor effects (Clark & Watson, 1995). Additionally, standard deviations showed satisfactory variation (i.e., $SD > 1$ according to Whitley & Kite, 2013). Only three items did not satisfy these criterions, but given this small proportion, we decided to retain them for the factor analysis.

3.2. Iterative exploratory analysis and item refining

We run a principal component analysis with promax rotation on the food rejection scores for all 168 respondents' children on the 35-item scale (N_1). The optimal number of factors was assessed with the Kaiser criterion (only the factors with eigenvalues above one are selected; Kaiser, 1960) and Cattell's scree plot criterion (determination of the point where the last important eigenvalues drop appears; Cattell, 1966). Following these two criterions, primary analysis indicated that the optimum number of factors was two, with an eigenvalue of 13.98 for the first factor (explaining 40% of the variance) and an eigenvalue of 3.99 for the second factor (explaining 11% of the variance). The other factors' eigenvalues were close to or below 1. In total 51% of the variance was explained by the two-factor model which had an inter-factor correlation of 0.62.

Examination of factor loadings showed that the majority of items loaded rather strongly on one underlying factor. However, 15 items proved problematic: Items P1, P7, P9 did not load on the anticipated factor (these three items were extracted from existing tools measuring pickiness and yet loaded on the same latent factor that items supposedly measuring neophobia), Items P2, P8, P11 and N5, had medium loadings on both factors, N8 had extremely low loadings (< 0.1) and the comments made by participants revealed that Items P12–P18 were indistinguishable from items N12–N17 (the participants were not able to distinguish the term *difficile*, translated as *picky*, from the expression *ne goûte pas un nouvel aliment*, translated as *won't try a novel food).* We therefore decided to remove these 15 problematic items from the scale (P1, P7, P8, P9, P11–18, N5 and N8). Moreover, the test of internal consistency (Cronbach's alpha coefficient) showed some redundancy between items ($\alpha = 0.96$), and inspection of the correlation matrix confirmed that some items were strongly correlated. Items N14–17 were all removed because they were closely correlated with Item N9 (all Pearson coefficients above 0.62). Items N3 and N11–13 were also removed to ensure a balance between the subscales. Altogether, 24 of the 35 items were removed. We then re-analyzed the data using the new and shortened version (11 items) of the scale.

Examination of the second scree plot indicated that it was suitable to extract two factors, with an eigenvalue of 3.77 for the first factor (explaining 34% of the variance) and an eigenvalue of 2.38 for the second factor (explaining 22% of the variance). Therefore, the two-factor model explained 56% of the variance with an inter-factor correlation of 0.54. Examination of factor loadings showed that all the items loaded rather strongly on the anticipated factors (Table 1), and internal consistency was good ($\alpha = 0.87$). We therefore run a confirmatory factorial analysis (CFA) with the 11-item scale and to assess its psychometric properties. The 11- item scale resulting from the iterative exploratory analysis contained 6 items relating to food neophobia and 5 items relating to pickiness (all items derived from previous questionnaires for the pickiness subscale were removed during this item refining process).

4. Main experiment: validation of the questionnaire

4.1. Methods

4.1.1. Participants

The 11-item questionnaire was administered to 274 parents either recruited online on food blogs or social networks, or from schools through flyers posted in the Lyons urban area (France) with no exclusion criteria, who each responded for their child aged between 2 and 7 years. None of them had been involved in the preliminary experiment. Parents who were not direct caregivers ($n = 3$) or who did not complete the entire survey ($n = 15$) were extracted from the study, that left us with a second sample N_2 of 256 caregivers (mainly mothers). As in the preliminary experiment, caregivers rated each item according their child's behavior (130 girls and 126 boys aged 22–84 months, mean age = 47 months, $SD = 15$) at the time of their convenience on a 5-point Likert-like scale (*Strongly disagree*, *Disagree*, *Neither agree nor disagree*, *Agree*, *Strongly agree*). Each answer was then numerically coded with a high score indicating high food rejection (scores could range from 11 to 55). Participants were informed they will receive a booklet providing nutritional advice and tips for recipes after completion of the survey. This main experiment was performed in adherence with the principles established by the declaration of Helsinki.

4.1.2. Convergent and discriminant validity

In order to assess the scale's convergent and divergent validities, 67% of the sample N_2 (172 caregivers) also filled in the Food Attitude Survey (FAS) (Frank & van der Klaauw, 1994) and the French version of the Revised Children's Manifest Anxiety Scale (RCMAS) (Turgeon & Chartrand, 2003) for their child (the completion to these questionnaires was not mandatory explaining the loss of participants, but caregivers had the choice of filling these additional questionnaires after completion of the first and main questionnaire). The subsample included 85 caregivers of girls and 87 caregivers of boys, and these children were aged between 22 and 84 months (mean age = 46 months, *SD* = 15).

In the FAS questionnaire, which was successfully translated into French by Ton Nu (1996), adults are questioned to specify the extent to which they approve or not ten declarations about eating practices (e.g., "I find that many foods I like are sweet") on a 5-point Likert-like scale. We selected the FAS to evaluate convergent validity as this questionnaire has been used to measure attitudes toward familiar and new foods, and has been shown to have sound internal consistency (Frank & van der Klaauw, 1994; Raudenbush, Schroth, Reilley, & Frank, 1998). It is worth noting that we could have used the QENA (Rubio et al., 2008) or the CEBQ (Wardle et al., 2001) to assess the convergent validity of our scale as they are entirely psychometrically valid. However we decided to use the FAS because the QENA is a self-assessment questionnaire used to measure only neophobia and the CEBQ was not translated in French and did not distinguish between neophobia and pickiness.

In the other hand, the RCMAS asks participants to answer "yes" or "no" to 36 statements about anxiety and low esteem issues, such as "I worry a lot of the time". We selected this scale to evaluate discriminant validity because although it assesses anxiety and not food rejection, food rejection is sometimes associated with high anxiety toward food items (Galloway et al., 2003). Thus, we expected to find medium to high positive correlation values between FAS scores and food rejection scores, and lower positive correlation values between RCMAS scores and food rejection scores.

4.1.3. Test–retest reliability

To evaluate the scale's reliability, 44% (n = 74) of the sample N_1 underwent a retest procedure. These parents twice completed online the 11-item version of the scale with a four-week interval in between (the completion to this second session was not mandatory explaining the loss of participants). The test–retest sample included 37 caregivers of girls and 37 caregivers of boys, and these children were aged between 22 and 84 months (mean age = 49.1 months, *SD* = 16.8).

4.1.4. Predictive value of the questionnaire

As in the seminal study by Pliner and Hobden (1992), we administered a food choice task to an additional sample of 17 children aged 31–78 months (mean age = 57 months, *SD* = 15) to evaluate the predictive validity of our scale. Children took the test individually in a quiet room during the time of the mid-morning break (which is usually taking place inside the classroom around 10 am) and were led to believe that they would be able to choose that day's menu in their cafeteria. They were told that many foods were available and they had to choose between them. Following the procedure used by Pliner and Hobden (1992), we used color photographs of real foods as the material for the choice test. Eight pairs of food pictures were shown successively to the children (four pairs were designed to measure neophobia and four to measure pickiness, see Table 2). These pictures were placed on a plastic plate to remind the children of an eating context.

To avoid misleading between food rejection and religious or widespread eating habits such as vegetarianism, we excluded the meat and fish categories. In the one hand each pair measuring neophobic behaviors contained one *a priori* known food and one *a priori* unknown food in the same general category (for example in one pair children had to choose between an apple and a persimmon, see Table 2, line 2), and data collection from the children supported this classification: the participants' mean familiarity ratings (the mean was assessed by attributing a score of 0 when the child told the experimenter he/she did not know the food and 1 when he/she told the experimenter she did know it), averaged across foods, were 0.08 for the four novel foods and 0.72 for the four familiar ones. These means were significantly different (t = 4.03, P = 0.02). In the other hand, each pair measuring picky behaviors contained a picture of a classical and familiar canteen dish with the different components sorted and separated from each other and a picture of the same dish but with the different components stirred together (for example in one pair children had to choose between a fruit salad with pears in one side, apples in the other and a fruit salad were apples and pears were mixed together, see Table 2, line 2).

For each of the eight pairs (presented in a counterbalanced order), set out in Table 2, the children were asked to choose the member of the pair they were willing to taste later at the canteen. For each participant, a caregiver was required to complete the 11-item scale in order to associate the children's food choice scores with their food rejection scores.

4.1.5. Data analysis

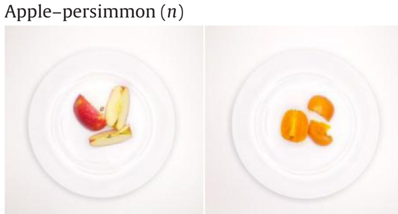
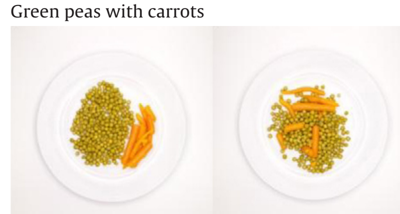
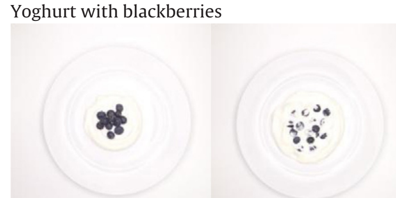
For each child, we calculated a food rejection score ranging from 11 to 55, based on the caregiver's answers. Preliminary analyses were run on these scores to check if the data were normally distributed (Shapiro's test). Then a confirmatory factor analysis (CFA) was conducted, using the maximum likelihood method. Finally, we conducted psychometric analyses to validate the final short version of the scale. First, we assessed our scale's reliability by calculating its internal consistency (Cronbach's alpha coefficient), and its temporal stability by assessing its test–retest reliability (we compared the mean values obtained for each session with paired Student's t test). Second, we assessed our scale's convergent, discriminant and predictive validity (Pearson and Spearman correlation coefficients). Finally, the mean food rejection scores for each sex were measured and compared (Student's t test), and correlations between food rejection scores and children's age were assessed (Pearson correlation coefficient). We set the alpha level at 0.05 for all statistical analyses. R 3.1.2 software and LISREL 9.10 (Jöreskog & Sörbom, 2012) were used to realize the statistical analyses.

5. Results

5.1. Preliminary analysis

Food rejection scores ranged from 11 to 55 (M = 34.8, SD = 8.6). Results from Shapiro's test indicated that the food rejection scores were normally distributed (w = 0.99, P = 0.38, *ns*). Screens for appropriate item variability revealed moderate means (between 2 and 4 on the 5-point Likert-like scale) and sufficient variability (SD > 1). Only one item failed to meet this criterion, but given this small proportion, we decided to retain this item for the CFA.

Table 2
Pairs of foods used in the food choice task.

Food categories	Food pairs used for neophobia	Food pairs used for pickiness
Starchy products	Ordinary rice–black rice (*n*) 	Pasta with tomato sauce 
Fruit	Apple–persimmon (*n*) 	Fruit salad 
Vegetables	Green beans–winged beans (*n*) 	Green peas with carrots 
Dairy products	Cow's milk cheese–tofu (*n*) 	Yoghurt with blackberries 

The novel foods are marked *(n)*.

5.2. Confirmatory factor analysis (CFA)

We ran a CFA to test the two-factor model's fit to the 11-item scale, using the maximum likelihood method with LISREL 9.10 (Jöreskog & Sörbom, 2012). Items N1, N2, N4, N6, N7 and N10 loaded on the first latent factor, named *food neophobia*, and Items P3, P4, P5, P6 and P10 loaded on the second latent factor, named *food pickiness*. Fig. 1 displays the path diagram yielded by the CFA for the two-factor solution.

Fig. 1 shows satisfactory factor loadings for each latent factor (range: 0.42–0.81), and a strong correlation between the two latent factors (r = 0.76). The CFA yielded acceptable fit indices: goodness-of-fit index (GFI) = 0.958, comparative fit index (CFI) = 0.981, root mean square error of approximation (RMSEA) = 0.041 and Chi^2/df = 1.42, as recommended by Wheaton, Muthén, Alwin, and Summers (1977), and Jackson, Gillaspy, & Purc-Stephenson (2009). Thus, the two-factor model was fully relevant. It is worth noting that even if we found strong correlation between food neophobia and pickiness, the two-factor model was more relevant that the one-factor model (which displayed poorer fit indices: GFI = 0.92, CFI = 0.93, RMSEA = 0.076 and Chi^2/df = 2.47). We then assessed the psychometric proprieties of the final 11-item scale.

5.3. Internal consistency

Internal consistency of the final 11-item scale was satisfactory overall (Cronbach's α = 0.87), as well as for each subscale (α = 0.87 for the neophobia subscale and α = 0.69 for the pickiness subscale).

5.4. Convergent and discriminant validity

Spearman's coefficient indicated that food rejection scores were significantly closely correlated with FAS scores (r = 0.81, P < 0.001). This correlation was positive, indicating that a high food rejection score corresponded to a high FAS score. This result attested to the convergent validity of our questionnaire. Additionally, food rejection scores were significantly and positively correlated with RCMAS scores, as indicated by Pearson coefficient (r = 0.33, P < 0.001). This correlation was positive, albeit much more moderate, indicating that our scale was discriminantly valid. It should be noted that we observed the same correlation ranges for each subscale (strong correlations between neophobia or pickiness scores and FAS scores respectively.75 and .4, and moderate correlations between neophobia or pickiness scores and RCMAS scores, respectively 0.19 and 0.21).

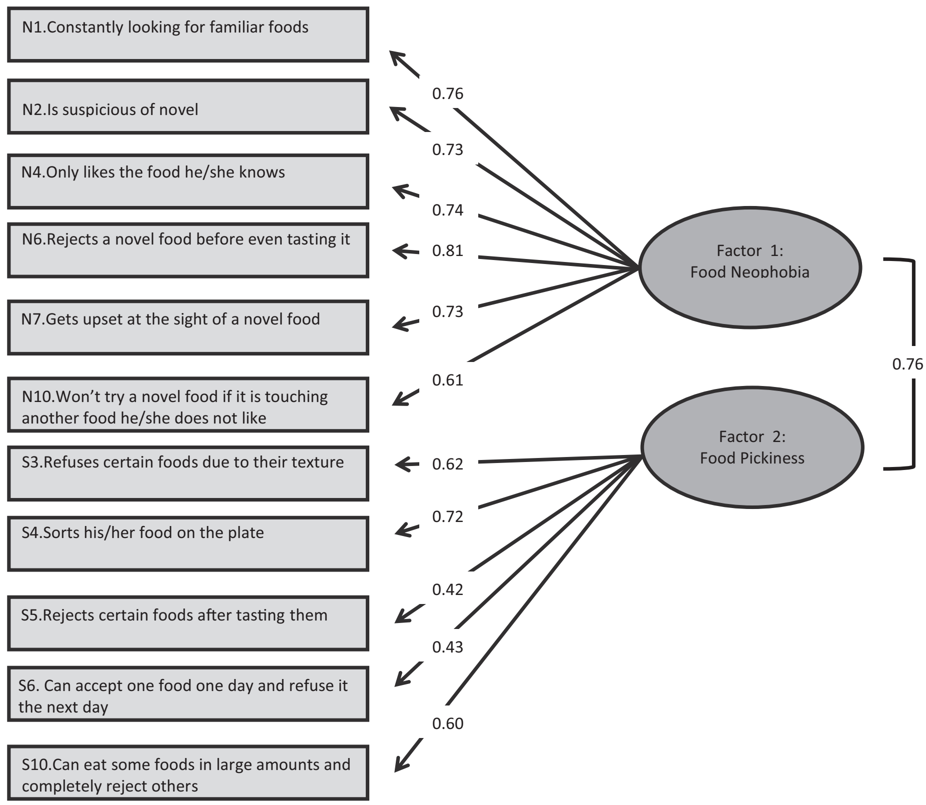


Fig. 1. Path diagram yielded by the confirmatory factor analysis.

5.5. *Test–retest reliability*

Table 3 sets out the mean scores at test and retest for the 11-item version of the scale. Paired t-tests indicated that variations in the mean rejection scores between test and retest were not significant (all $Ps > 0.5$). These findings show that the final food rejection scale had satisfactory test–retest reliability.

5.6. *Predictive value of the questionnaire*

The degree to which a child behaved in a picky and neophobic manner was defined as the numbers of pairs for which he/she chose the familiar/sorted food for later tasting, divided by the total number of pairs ($N = 8$). Indeed if a child chose the familiar item in the pairs measuring neophobia (ordinary rice, apple, green beans and cow cheese) he/she behaved in a neophobic manner as neophobic children are reluctant to taste novel food items. Additionally, for pairs measuring pickiness if he/she chose the picture were foods were sorted, he/she behaved in a picky manner because picky children often sort their food in the plate.

A correlation analysis using Spearman's correlation coefficient across the children indicated that questionnaire scores and children's choice of familiar/sorted foods were significantly correlated ($r = 0.48$, $P = 0.049$). This correlation was positive, indicating that a high food rejection score corresponded to a high number of familiar/sorted foods chosen during the task (Fig. 2).

5.7. *Variations in food rejection scores according to children's sex and age*

Results from mean comparisons using a t test showed that boys and girls did not differ significantly on food rejection scores ($t = 0.67$, $P = 0.49$, *ns*). We observed the same absence of sex effect for each subscale (both p values > 0.3). Finally, correlation coefficients

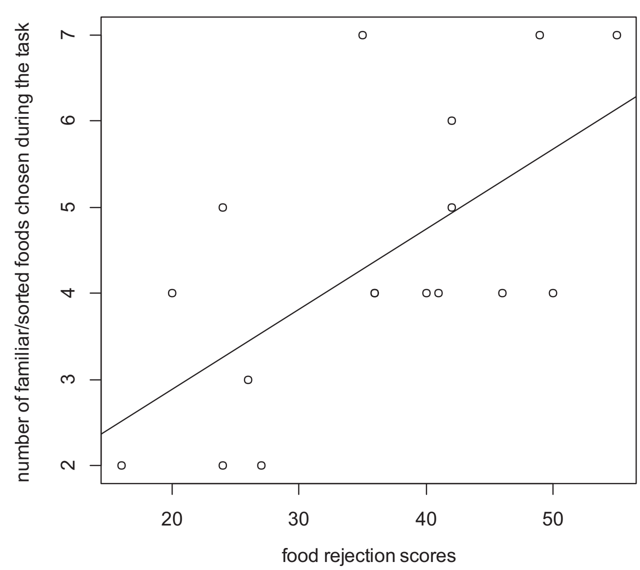


Fig. 2. Correlation between behavioral and questionnaire measures of neophobia and pickiness for our sample of 17 children.

indicated that neither the neophobia, pickiness nor total food rejection scores were significantly correlated with age (all $rs < 0.13$, *ns*). We also assessed Spearman correlations between age and each of the 11 items, to see whether any item was more closely correlated with age than the others, but results indicated that none of the items were correlated with age (all $rs < 0.15$).

6. General discussion

The threefold aim of this study was to:

Table 3
Mean scores and standard deviation (SD) on the 11-item scale at test and retest ($n = 74$). Comparisons between mean values made using paired t-tests.

Item	Test		Re-test		*t*-test	
	Mean	*SD*	Mean	*SD*	*P* value	
P3	3.3	1.2	3.3	1.2	0.53	*ns*
P4	3.3	1.2	3.1	1.2	0.07	*ns*
P5	3.9	0.7	3.8	0.8	0.32	*ns*
P6	3.4	1.3	3.4	1.2	0.64	*ns*
P10	4.0	1.1	3.9	1.1	0.54	*ns*
Overall P	17.9	5.5	17.5	5.6	0.18	*ns*
N1	3.2	1.2	3.1	1.2	0.61	*ns*
N2	3.2	1.2	3.1	1.2	0.45	*ns*
N4	2.6	1.2	2.6	1.1	0.67	*ns*
N6	3.0	1.3	2.9	1.2	0.27	*ns*
N7	2.0	1.1	2.1	1.0	0.60	*ns*
N10	2.6	1.1	2.5	1.1	0.82	*ns*
Overall N	16.5	4.0	16.3	4.2	0.59	*ns*
Overall	34.4	8.6	33.9	9.0	0.24	*ns*

Ns: no significant difference. *** $P < 0.001$.

- validate a new food rejection scale that would simultaneously measure food neophobia and pickiness, thereby filling a gap in the psychometric assessment of food rejection by young French children;
- clarify the definition of pickiness;
- unpick the relationship between food neophobia and pickiness, as well as the developmental paths of these two constructs. To our knowledge, ours was the first attempt to design a scale that included pickiness and food neophobia as two possible dimensions of food rejection by children, and which had all the properties of a reliable test.

First, our findings showed that the final 11-item food rejection scale, which we named the Child Food Rejection Scale (CFRS), displayed good psychometric properties (it is important to note that in the final scale, half of the retained items of the neophobia subscale were adapted from the FNS (Pliner & Hobden, 1992), while all the pickiness subscale's retained items were created for this research). Reliability, as measured through internal consistency and test–retest reliability was satisfactory, with coefficients comparable to those found in previous research on children's food neophobia or pickiness when it was measured. For instance, Rubio et al. (2008) reported a Cronbach' alpha of 0.84 and a Pearson coefficient of 0.74 for the test–retest reliability of their neophobia scale, while Rigal et al. (2012) reported an alpha of 0.73 for their fussiness subscale (Rubio et al., 2008; Rigal et al., 2012). The construct validity of the CFRS was also adequate, as attested by measures of convergent and discriminant validity. Results further showed that the predictive validity of our scale was satisfactory: using food pictures was an efficient strategy for measuring food choice, as proposed by Guthrie, Rapoport, & Wardle (2000), as well as by Rubio et al. (2008). Although significant, the correlations between food rejection scores and food choices were quite moderate. As pointed out by Laureati et al. (2015), the use of real food items, might have led to stronger correlations. Nevertheless, to offset the limitations of using of food pictures, we tested the children in an ecological environment, namely the room where they usually have their morning snack, as ecological validity can be achieved with real-world stimuli as well as with natural settings. The correlation obtained within this sample was nevertheless within the range of those previously found by studies assessing the predictive validity of the FNS ($r = 0.43$ in Loewen & Pliner, 2000; $r = 0.43$ in Pliner & Hobden, 1992; $r = 0.34$ in Rubio et al., 2008). It is also interesting to note that these studies used self-assessment questionnaires, whereas we used proxy assessment. Therefore, we can reasonably assume that caregivers are relevant predictors of their children's behaviors toward foods.

Second, factor analyses supported the two-dimensional structure of our scale, namely the distinction between food neophobia and pickiness in young children refuting Wardle et al. (2001) position i.e. neophobia and pickiness are indistinguishable. There was, however, a strong positive correlation between these two kinds of food rejection, indicating that they are closely related (i.e., a child with a high neophobia level was likely to display a high pickiness level as well). These findings are in line with the claims of Potts and Wardle (1998), Raudenbush et al. (1995) and Rigal et al. (2012). They also partly explain the view put forward by Dovey et al. in their review (2008) that some social factors, such as pressure to eat and parental practices/styles, have similar effects on the severity of expressions of both food neophobia and pickiness. Concerning the developmental paths of food rejection, the pattern we found for food neophobia is consistent with the view put forward by Addessi et al. (2005), Cooke et al. (2003), and Koivisto and Sjöden (1996), that neophobia increases promptly around 2 years of age, when children are liable to ingest poisonous compounds because of their increasing mobility, and remains quite stable until 6–7 years. For pickiness, the absence of changes in its prevalence with age is consistent with the view of Dubois et al. (2007). However, as pointed out by a recent research review of pickiness undertaken by Taylor et al. (2015), consensus on the developmental path of pickiness will only be reached if an agreement on the definition is achieved and assessment across study is undertaken with homogenous and fully validated tools. Finally, we found no evidence that food rejection (either neophobia or pickiness) varied across the sexes in early childhood. This finding is consistent with previous results for sex comparisons in food rejection by young children (see Koivisto-Hursti & Sjöden, 1997, for food neophobia, and Xue et al., 2015, for pickiness), and is particularly noteworthy, for in teenagers, there are generally clear sex differences in attitudes toward food, attributed partly to social factors such as girls' growing concerns about their weight and body image (Wardle et al., 2001). It would hence be interesting to follow the developmental path of sex differences across the years, to better understand the respective roles of cognitive and social factors in food rejection.

We acknowledge that there were several limitations to this study. First, the fairly moderate response rate to the questionnaire led us to presume that it was mainly filled in by families interested with nutrition, and hence not entirely representative of the national population. Further studies could thus extend the investigation of children's food rejection assessment to more representative and generalizable samples and to test the applicability of the scale for non-French children. Second, we lacked dual-caregivers reports or children perspective on their own food neophobia and pickiness. Further studies could therefore assess the concordance of caregiver ratings for the same child or the concordance of children and caregiver ratings (for an older child who could answer for their own to the questionnaire). Third, it would seem that the subscale for neophobia is more robust and consistent than that for pickiness, which has a lower consistency. Pickiness is a construct which is still not well defined and further studies are much needed to better grasp this construct. Finally, in our food choice task, the food pictures used to measure pickiness were based on only one aspect of this construct (namely that a picky child is likely to sort his/her food), whereas its definition also includes the consumption of an inadequate amount of food or the rejection of certain food textures. In future research, therefore, it would be worth assessing the predictive validity of the CFRS with another feature of picky behaviors (e.g., by presenting children with foods of different textures). Nevertheless, despite these limitations, we believe that the CFRS represents an efficient and valuable tool for studying food rejection tendencies in young French children through their caregivers. This new scale could be useful for measuring the effectiveness of interventions promoting the adoption of healthier food habits, by children.

Disclosure of interest

The authors declare that they have no competing interest.

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Appendix. Thirty-five-item version of the CFRS.

Pickiness subscale.

P1 = **mon enfant accepte une variété limitée d'aliments (**my child accepts only a small variety of foods, *adapted from the CEDQ;* Rigal et al., 2012).

P2 = **mon enfant mange en petites quantités** (my child eats in small quantities, *novel item*).

P3 = **mon enfant refuse de manger certains aliments à cause de leurs textures** (my child refuses certain foods due to their texture, *novel item*).

P4 = **mon enfant fait le tri dans son assiette** (my child sorts his/her food on the plate, *novel item*).

P5 = **mon enfant rejette certains aliments après les avoir goûté** (my child rejects certain foods after tasting them, *novel item).*

P6 = **mon enfant peut manger un aliment aujourd'hui et le refuser demain** (my child can accept a food one day and refuse it the next day, *novel item*).

P7 = **il est difficile de faire plaisir à mon enfant avec un plat que j'ai cuisiné** (my child is difficult to please with homemade meals, *adapted from the CEBQ;* Wardle et al., 2001).

P8 = **mon enfant préfère lorsque les aliments sont en petites quantités dans son assiette** (my child prefers having small quantities on the plate, *novel item*).

P9 = **une mauvaise expérience alimentaire empêche mon enfant de goûter l'aliment à nouveau** (a bad experience would keep my child from trying a food again, *from the FAS;* Frank & van der Klaauw, 1994).

P10 = **mon enfant peut manger certains aliments en grandes quantités et d'autres pas du tout** (my child can eat some foods in large amounts and completely reject others, *novel item*).

P11 = **mon enfant est sélectif pour la nourriture** (my child is a picky eater, *novel item*).

P12 = **mon enfant est difficile avec la nourriture lorsqu'un aliment est en contact avec autre aliment qu'il n'aime pas** (my child is picky when one food touches another food that he/she does not like, *novel item*).

P13 = **à la cantine scolaire, mon enfant ne mange qu'une partie des aliments proposés** (in the school canteen my child eats only a small variety of foods, *novel item*).

P14 = **quand on mange chez des amis, mon enfant fait le tri dans son assiette** (when we eat with friends my child sorts his/her food on the plate, *novel item*).

P15 = **mon enfant est difficile pour la nourriture même en présence de camarades faciles pour la nourriture** (my child is picky even when he/she is with friends who are not picky eaters, *novel item*).

P16 = **mon enfant est difficile pour la nourriture quand il est invité à des fêtes** (my child is picky when he/she is invited to parties, *novel item*).

P17 = **mon enfant est difficile pour la nourriture même si on lui dit que ce qu'il y a dans son assiette a bon goût** (my child is picky even if we tell him/her that the food on the plate is tasty, *novel item*).

P18 = **mon enfant est difficile pour la nourriture même si on ajoute un aliment qu'il aime dans son assiette** (my child is picky even if we add a food he/she likes on the plate, *novel item*).

Neophobia subscale.

N1 = **mon enfant recherche constamment des aliments familiers** (my child is constantly looking for familiar foods, *adapted from the FNS;* Pliner & Hobden, 1992).

N2 = **mon enfant se méfie des aliments nouveaux** (my child is suspicious of new foods, *adapted from the FNS;* Pliner & Hobden, 1992).

N 3 = **si mon enfant ne sait pas ce qu'il y a dans un plat, il n'y goûte pas (**if my child does know what is in a food, he/she won't try it, *from the FNS;* Pliner & Hobden, 1992).

N4 = **mon enfant aime seulement la cuisine qu'il connaît** (my child only likes the food he/she knows, *adapted from the FNS;* Pliner & Hobden, 1992).

N5 = **mon enfant ne goûte pas un nouveau plat si un de ses ingrédients lui déplait** (my child won't taste a dish if he/she dislikes one of its components, *adapted from* Ton Nu, 1996).

N6 = **mon enfant rejette un nouvel aliment avant même de l'avoir goûté** (my child rejects a novel food before even tasting it, *novel item*).

N7 = **mon enfant est angoissé à la vue d'un nouvel aliment** (my child gets upset at the sight of a novel food, *novel item*).

N8 = **mon enfant aime identifier chacun des aliments présents dans son assiette** (my child likes to identify each of the foods on the plate, *novel item*).

N9 = **mon enfant a peur de goûter des aliments nouveaux** (my child is afraid to taste novel foods, *adapted from the QENA;* Rubio et al., 2008).

N10 = **mon enfant ne goûte pas un nouvel aliment si cet aliment est en contact avec un autre aliment qu'il n'aime pas** (my child won't try a novel food if it is touching another food he/she does not like, *novel item*).

N11 = **à la cantine scolaire, mon enfant refuse de manger des aliments nouveaux** (at school canteen, my child refuses to eat novel foods, *novel item).*

N12 = **mon enfant montre des signes d'anxiété lorsque l'on va manger chez des amis** (my child gets anxious when we eat with friends, *adapted from the FNS;* Pliner & Hobden, 1992).

N13 = **quand on mange chez des amis, mon enfant choisit des plats qu'il connaît** (when we eat with friends, my child picks foods he/she knows, *adapted from the FNS;* Pliner & Hobden, 1992).

N14 = **mon enfant évite les aliments nouveaux même en présence de camarades goûtant à ces aliments** (my child avoids novel foods even when he/she is with friends trying these new foods, *adapted from the QENA;* Rubio et al., 2008).

N15 = **mon enfant évite les aliments nouveaux quand il est invité à des fêtes** (my child avoids novel foods when he/she is invited to parties, *adapted from the QENA;* Rubio et al., 2008).

N16 = **mon enfant ne goûte pas un nouvel aliment même si on lui dit qu'il a bon goût** (my child won't try a novel food even if we tell him/her it is tasty, *adapted from the QENA;* Rubio et al., 2008).

N17 = **mon enfant ne goûte pas un nouvel aliment même si on ajoute un aliment qu'il aime dans son assiette** (my child won't try a novel food even if we add a he/she likes on the plate, *adapted from the QENA;* Rubio et al., 2008).

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PART C. BRINGING KNOWLEDGE TO THE TABLE: THE DEVELOPMENT OF FOOD CATEGORIZATION AND REJECTIONS IN YOUNG CHILDREN

Chapter 6. Food rejection and the development of food categorization in young children

This chapter focuses on the investigation of the relationship between categorization development in young children and their food neophobia and pickiness.

Several kinds of tasks are commonly used to assess toddlers and preschoolers' categorization performances (e.g., sequential touching procedures, forced and free sorting tasks, etc.; Bonthoux, Berger, & Blaye, 2004; Murphy, 2002). The instructions in these tasks, as well as stimuli presentation, have been shown to impact categorization strategies and choices (Bonthoux, et al., 2004). Therefore when investigating categorization abilities during the sensitive period for food rejections (2-6 years of age), it is important to propose the same task to 2-year-old children and 6-year-old-children, to avoid any cofounding effects due to experimental design. Methodologies where children are asked to sort pictures are suitable for a large age range (Bonthoux et al., 2004). 2-year-old children can sort apart a small set of different pictures (Guignard, 2000), and this sorting activity are similar to every day task for preschoolers (Bovet, Vauclair & Blaye, 2005). Because the focus was on children' taxonomic categorization abilities in the food domain, a forced sorting task was used. Children were explicitly asked to sort pictures according to taxonomic food categories. Because children often prefer to use thematic relations to freely sort apart different pictures, even if they know the taxonomic relations, a free sorting task was not a suitable methodology (Murphy, 2002).

To investigate the relationship between categorization performances and food rejection dispositions, both the Children Food Rejection Scale (CFRS) developed previously, and a behavioral food rejection task were used. The correlation between CFRS scores and categorization scores was considered to investigate the relationship between an immature food categorization system and children dispositions to reject foods, when presented with a new food item. The correlation between behavioral food rejections and categorization scores was considered to investigate precisely the relationship between categorization ability for a particular food item and possible rejection ensuing for this particular food item.

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Food rejection and the development of food categorization in young children

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ABSTRACT

Food rejection and food categorization are the hallmarks of the omnivore's dilemma, but little is known about the former's development or its relationship with the latter in children. We recruited 79 children aged 2–6 years and 30 adults to test the hypotheses that (i) children's food categorization starts to improve at 2 years, (ii) their food rejection is intrinsically linked to development of the food categorization system, and (iii) food categorization relies mainly on color, which conveys information about food typicality. In a categorization task, participants were shown color photographs of fruit and vegetables, and asked to put items belonging to the same category in the same box. Results on accuracy indicated an age-related increase in food categorization performances, and provided the first empirical evidence speaking in favor of i) a relationship between children's food rejection and food categorization, and ii) the central role of color typicality in food categorization.
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1. Introduction

Food is of central biological importance to humans, but while "trying new foods is at the core of omnivorousness (. . .) so is being wary of them" (Rozin, 1976). As insightfully stated by Rozin, humans, along with other omnivorous species, are caught on the horns of this omnivore's dilemma. Humans need to have a diverse diet to ensure their nutritional health, survival, and reproduction. To satisfy this dietary diversity, they must therefore continually sample new food resources, as they move away from a mono diet, namely their mother's milk, to a diverse food repertoire. However, this search for variety can prove hazardous, as new substances may be toxic, and a single mistake in this search could potentially lead to death, and thus hinder reproduction (generally associated with evolutionary success; Dakwins, 1976).

Two design features appear to have emerged through natural selection to solve this adaptive problem.[1] Grasping the first horn of the dilemma, a categorization system allowing for a food/nonfood distinction and discrimination between different food items enables efficient sampling of new food resources and enrichment of the food repertoire. Categorization is a fundamental cognitive process that allows us to organize objects into groups (Vauclair, 2004). Without such abilities, each item would be perceived as new, and it would be impossible to generalize its properties (such as assuming that because a carrot is edible, other carrots will be too; Murphy, 2002).

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[1] An adaptive problem is a problem, like this omnivore's dilemma, whose solution can affect reproduction, and hence evolutionary success (Cosmides, Tooby, & Barkow, 1992).

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Grasping the second horn of the dilemma, *food neophobia* (defined as the reluctance to eat novel food items; Pliner & Hobden, 1992) and *food pickiness* (defined as the rejection of a substantial amount of familiar foods, the consumption of an inadequate amount of food, and the rejection of certain food textures; Rydell, Dahl, & Sundelin, 1995; Smith, Roux, Naidoo, & Venter, 2005; Taylor, Wernimont, Northstone, & Emett, 2015) prevent individuals from ingesting substances that are potentially poisonous (Cashdan, 1994; Pliner, Pelchat, & Grasbski, 1993; Rozin, 1977). It has been reported that these rejection behaviors are mainly targeting plants, fruits and vegetables (Dovey, Staples, Gibson, & Halford, 2008). This is in line with recent evidence showing that infants as young as eight months old exhibit greater reluctance to touch basil and parsley plants, compared to plastic artefacts in the absence of social information (Wertz & Wynn, 2014a).

However, while these food rejection behaviors had an adaptive value in Pleistocene hunter-gatherers' hostile food environment, in our modern societies, where food safety is controlled in food supply chains, they are less useful. Indeed, as food rejection behaviors lead to a low consumption of fruit and vegetables by young children (Dovey et al., 2008), they are responsible for a reduction in dietary variety (Birch & Fisher, 1998; Falciglia, Couch, Gribble, Pabst, & Frank, 2000) needed for normal and healthy child development (Carruth et al., 1998; Cashdan, 1998).

The assumption that food rejection and food categorization processes are natural selection's solutions to the omnivore's dilemma led us to compare the scientific literature on food rejection and on children's cognitive development, in particular the development of a food categorization system (Lafraire, Rioux, Giboreau, & Picard, 2016). This comparison, which we expected to shed light on the mechanisms underlying food rejection behaviors from the perspective of overcoming them, uncovered several interesting outcomes or hypotheses.

First, an increasing number of research studies have related eating disorders to abnormal cognitive development, such as in autism spectrum disorder (Postorino et al., 2015; Rochedy & Poulain, 2015; Stough, Gillette Roberts, Jorgensen, & Patton, 2015). Children with autism are known to have cognitive deficits (Frith & Happé, 1994; Ozonoff, Pennington, & Rogers, 2015), and interestingly eating problems are common in this clinical population (Ahearn, Castine, Nault, & Green, 2001). Approximately 80% of young children on the autism spectrum are described as picky eaters, and 95% of them are reported by parents to be resistant to trying new foods (Lockner, Crowe, & Skipper, 2008) while prevalence of picky eating in young neurologically typical children usually ranges from 25% to 50% (Taylor et al., 2015). Moreover, Bandini et al. (2010) found that children with autism had more limited food repertoires than typically developing children.

Second, the sensitive period for food rejection starts at around 2 years, when children become mobile and begin to reason about food items other than through their caregivers[2] (Cashdan, 1994; Dovey et al., 2008; Lafraire et al., 2016). It is precisely at this point that a food categorization system is assumed to take its place within the child's cognitive system. Before the age of 2 years, infants exhibit very limited food categorization abilities. For instance, using a sequential touching procedure, Brown (2010) found that 20-month infants did not systematically distinguish between food and animal categories. In the same vein, using a looking time procedure, Shutts, Condry, Santos, and Spelke (2009) showed that 9-month-old infants direct their attention equally to domain-relevant properties (e.g., color and texture) and to domain-irrelevant properties (e.g., shape of the food's container) when reasoning about food. However, a rapid change occurs between 2 and 3 years of age. Using a sorting task procedure, Bovet, Vauclair, and Blaye (2005) found that 3-year-olds systematically distinguished between toy items and food items, demonstrating that these toddlers had developed a conceptual food category. Moreover, Brown (2010) established that, at this age, children also differentiate between categories within the food domain, such as biscuit and fruit. These results are in line with Nguyen and Murphy's claim that taxonomic categories[3] are available to children quite early in development (Nguyen & Murphy, 2003).

Third, rejection usually occurs at the mere sight of the food (Carruth et al., 1998), leading some authors to hypothesize that as children wish to recognize the foods they are given (to be sure of the consequences of ingestion), there is a perceptual mismatch between the meal that is presented and the prototypical food representations in their mind, possibly leading to food rejection (Brown, 2010; Dovey et al., 2008). For instance, Dovey et al. (2008, p. 183) hypothesized that "children build up schemata of how an acceptable food should look, and perhaps smell, and so foods not sufficiently close to this stimulus set will be rejected".

Fourth and last, one important finding in the domain of food categorization is that children from the age of 2–3 years attend to information about color or texture, rather than shape (Landau, Smith, & Jones, 1988; Yoshida & Smith, 2003) when discriminating between edible and inedible substances or between different kinds of foods (Lavin & Hall, 2001; Macario, 1991; Ross & Murphy, 1999; Shutts, Kinzler, McKee, & Spelke, 2009). For example, in a conflicting picture triad procedure,[4] Macario (1991, Exp. 4) showed 3- to 4-year-old children a novel object, described as either a thing to eat (*food* condition) or a thing to play with (*toy* condition). The children were then introduced to two other novel objects: a *color match* with the target object; and a *shape match* with the target object. When asked which one was like the target object, children were more likely to choose the color-match object in the *food* condition, whereas they were more likely to choose the shape-match object

[2] Before this age, food reasoning and selection seem to be mainly driven by social information (Wertz & Wynn, 2014b). For example infants preferentially reach for food that had been endorsed by native speaker of their native language (Shutts, Kinzler et al., 2009). See Lafraire et al. (2016), Lumeng (2013) and Shutts, Kinzler & DeJesus (2013) for reviews of the social influences on food selection.

[3] Taxonomic categories are based on common properties and are organized into hierarchies, such as apple-fruit-food (Nguyen & Murphy, 2003).

[4] In a conflicting triad procedure, a target and two test items are pitted against each other. Children are required to match one of the test items with the target.

in the *toy* condition. These data speak in favor of a domain specificity[5] effect on categorization, and this domain specificity effect is relevant not only in nonlinguistic categorization tasks, as Macario established, but also in children's novel word extensions (Lavin & Hall, 2001).

Thus, if food rejection is a behavioral consequence of an immature food categorization system (Brown, 2010; Dovey et al., 2008; Lafraire et al., 2016) and food categorization is mainly color-dependent (Lavin & Hall, 2001; Macario, 1991), then some food colors should trigger food rejection. There is already some evidence to support this idea. Compared with orange vegetables (Gerrish & Mennella, 2001), green vegetables are often rejected more (Harris, 1993), and their acceptance is more difficult to foster (Mennella, Nicklaus, Jagolino, & Yourshaw, 2008). Additionally, Macario (1991) reported that many parents have anecdotally noted that their children can reject all foods of a particular color. To explain these mechanisms, Macario (1991, Exp. 2–3) showed 2- to 4-year-old children two photographs of familiar foods: one normally colored (e.g., a green lettuce) and one anomalously colored (e.g., a purple lettuce). The children were then asked which one was not for people to eat, and consistently chose the anomalously colored photograph. The author concluded that the toddlers had a hypothesis about the predictive validity of color in the food domain, and rejected foods were those that were not the color they were supposed to be.

To summarize, our comparison of the scientific literature on food rejection and the development of a food categorization system uncovered the following three outcomes and hypotheses:

(i) Children's ability to perform categorization in the food domain appears to improve from the age of 2–3 years. However, further studies are greatly needed, as there is still far too little research on food categorization in children, especially children over 3 years, when the food categorization system is thought to develop;

(ii) Food rejection may be a manifestation of a developing food categorization system that generates a large number of mismatches between food items and early food categories. Nevertheless, though promising, the explanation that food is rejected on account of its visual properties, through a mismatch between a prototypical category and a particular food item (proposed by Brown, 2010; and Dovey et al., 2008) needs further elaboration and refinement. These authors seemed to rely on the prototype theory of categorization proposed by Rosch and Mervis (1975), as they used notions proposed by this theory, such as *schemata* and *prototype* (Murphy, 2002). However, in this theory, a category is represented by a unified and summary representation of the different exemplars, rather than by separate representations for each member of the category (Murphy, 2002; Rosch & Mervis, 1975). Therefore, there is necessarily a mismatch between a new item and the prototype of the category (since it is not an exemplar but rather a feature list), and acceptance of a new item in the category is therefore based not on an exact match but rather on an acceptable similarity to the prototype (Murphy, 2002);

(iii) Food categorization is mainly color dependent, and some food colors trigger food rejection. However the precise mechanism linking food color and food rejection has yet to be identified. In our view, color is important mainly because it conveys information about the typicality of a given food exemplar contrary to shape or texture (which vary more across recipes and preparations). We would expect atypical items of a given category to be frequently excluded from that category (Murphy, 2002), and the anomalously colored photographs in Macario's experiments described above (1991), which were atypical items, were indeed excluded from the food category.

The present study was designed to investigate these three interesting outcomes and the gaps in these fields that would be well worth filling in, so as to shed light on the mechanisms underlying food rejection behaviors and possibly overcome them. The literature described above led us to formulate the following three hypotheses:

H1. Children's abilities to perform categorization in the food domain start improving at age 2–3 years. More specifically, discrimination abilities in the food domain should improve between 2 and 4 years and 4–6 years, and up to adulthood.

H2. Food rejection in young children is closely intertwined with the development of a food categorization system, with food rejection being the behavioral consequence of an immature food categorization system. From this perspective, we would expect children with poor discrimination abilities in the food domain to demonstrate higher food rejection tendencies than children with high discrimination abilities.

H3. Food categorization is mainly color dependent, but color is not important per se. Rather, it conveys information about the typicality of a given food exemplar. As a result, we would expect food items with atypical colors to be more prone to categorization errors than food items with typical colors.

To investigate these three hypotheses, we conducted a food categorization task with children aged 2–4 and 4–6 years (plus an additional control group of adults), involving the use of fruit and vegetable categories. We chose these categories because by this age, children have usually encountered several exemplars of these food items and developed the corresponding taxonomic categories (Nguyen & Murphy, 2003). Fruit and vegetables were also chosen because they are likely to be rejected by children in this age range. Moreover, to gain a sensitive measure of children's categorization abilities, we needed two categories that were not too distant from each other, regarding false relatedness effects (it is more difficult to answer "No" to the question "Is a vegetable a fruit?" than to the question "Is a vegetable a car?"; see Smith & Medin, 1981). It has been argued that from an early age, children distinguish accurately between natural items (e.g., food) and artificial items (Mandler & McDonough, 1993) and between categories within the food domain such as biscuit and fruit (Brown, 2010).

[5] According to Fodor (1983), many aspects of cognition are supported by specialized and specified learning devices.

2. Methods

2.1. Participants

The participants were 79 children: 40 children aged between 27 and 46 months ($M = 36.1$ months, $SD = 5.7$; 24 girls and 16 boys) and 39 children aged between 48 and 78 months ($M = 63.7$ months, $SD = 8.7$; 20 girls and 19 boys). The children were pupils at a preschool in the Lyons urban area (France), and were predominately European and recruited from middle-class communities. Prior to the study, the children's parents filled out a questionnaire about their food rejection (Child Food Rejection Scale,[6] CFRS; Rioux, Lafraire, & Picard, submitted) and exposure to the fruits and vegetables presented to the children during the experiment. The children's scores on the CFRS ranged from 16 to 50 ($M = 33.5$, $SD = 7.8$), and were normally distributed (Shapiro-Wilk test, $W = 0.98$, $p = 0.42$). These scores obtained via parental report were used as the predictive measure of children's own food rejection tendencies. Their exposure scores ranged from 3 to 10[7] ($M = 8.4$, $SD = 1.5$) and were not normally distributed ($W = 0.8$, $p < 0.05$). Neither of these scores (CFRS and exposure scores) were correlated with age (Pearson's correlation, $r = -0.13$, $p = 0.24$, and Spearman' correlation $r = 0.06$, $p = 0.6$) and neither varied according to sex (as attested by a Student's t test, both $ps > 0.06$). It is interesting to note that the absence of any influence of age on food rejection scores within this age range (2–6 years old) is consistent with previous findings (Addessi, Galloway, Visalberghi, & Birch, 2005; Cooke, Wardle, & Gibson, 2003; Koivisto & Sjöden, 1996; Rioux et al., submitted). It suggests that food rejections increase rapidly around the age of two years, when children are liable to ingest toxic compounds because of their growing mobility, remains quite stable until 6–7 years and slowly decrease thereafter when fewer foods are novel to children.

A control group of adults ($n = 30$) also performed the categorization task (Adult sample 1). These participants were either recruited from a university or were preschool employees. Two additional adult samples (Sample 2: $n = 79$ (children's parents); and Sample 3: $n = 10$) were used to rate the kind and color typicality of our food set.

2.2. Stimuli

Following Macario's lead (1991, Exp. 2 and 3), we tested the children with photographs of some familiar fruit and vegetables. Some photographs had typical colors (e.g., a purple beetroot), while some had atypical, but still real, colors (e.g., a yellow beetroot). The main difference between Macario's experiment and the present study was the use of only real food, that is to say, even if yellow is an atypical color for a beetroot, this variety can still be found in supermarkets and greengrocer's stores. None of our colors were anomalous for a given type of food.

To generate our set of foods, we first visited a school canteen to see which foods were available to children, and which recipes were usually proposed. On this basis, we selected six vegetables that were commonly served and were available in different colors (carrots, tomatoes, eggplants, beetroots, bell peppers and zucchinis), and three fruits (apples, pears and citrus fruits).[8] Next, to control for fruit and vegetable typicality, as several authors have demonstrated that typical items are easier to recognize and categorize (Hayes & Taplin, 1993; Mervis & Pani, 1980; Murphy, 2002), we followed Barsalou (1985)'s and Chrea, Valentin, Sulmont-Rossé, Hoang Nguyen, and Abdi (2005)'s methodologies. The parents of the children in our sample (Adult sample 2) were therefore asked to indicate on a 7-point scale for each of the nine food items whether they were good examples of the fruit or vegetable category in question. No pictures were used for this procedure. For example, we asked adult participants to imagine a carrot and then rate its typicality compared to other vegetables on the 7-point scale. The purpose of this first assessment was to determine whether in general, carrots were judged to be more typical than beetroots for instance. The results are set out in Table 1 and showed for instance, that carrots were judged to be more typical vegetables than beetroots because typicality's rating for carrot was judged to be 6.30 while it was judged to be 3.91 for beetroots.

For each of the six vegetables and three fruits, we chose four varieties differing in color. We then asked 10 adults (Adult sample 3) to indicate the typicality (either *typical* or *atypical*) of the color chosen for each vegetable and fruit (the typicality of the color for each food item was independent of its kind typicality assessed with the adult sample 2).[9] From this assessment we were able to know that the orange carrot was *typically colored* while the purple carrot was *atypically colored* for instance.

Finally, to control for shape effects, each food item was cut either into quarters, slices or cubes, ensuring that the chosen shape was the one in which a given vegetable/fruit was most commonly served in the school canteen we visited (e.g., beetroots were commonly served cut into small cubes, so this was the shape we chose for this vegetable; see Table 2). We decided to use cut fruit and vegetables instead of whole food items to gain in ecological validity. Indeed, as the purpose of

[6] The Child Food Rejection Scale is a short and easy-to-administer scale, in which caregivers respond for their child. It was developed to enable the assessment of food neophobia and pickiness in children aged 2–7 years, and includes two subscales: one measuring children's food neophobia and one measuring their pickiness.

[7] Children's scores on the Child Food Rejection Scale can range from 11 to 55. Their exposure scores can range from 0 to 10.

[8] We chose the citrus fruit family (and not just orange or grapefruit) because of the limited availability of fruits in different colors in the season the experiment was conducted.

[9] We chose a 7-point scale to assess fruit and vegetable typicality because we wanted to arrange the items according to their typicality in the different blocks of pictures. However, we followed Macario's lead and assessed color typicality with a binary scale, in order to gain an initial impression of the role of color typicality in food categorization.

Table 1
Typicality rated by adults (on a 7-point scale) for the entire food set.

Food items	Typicality rating	Typicality ranking
carrot	6.30	1
zucchini	6.14	2
tomato	5.33	3
bell pepper	4.60	4
eggplant	4.41	5
beetroot	3.91	6
apple	6.55	1
pear	6.29	2
citrus fruit	5.12	3

Note: For citrus fruit, we averaged the typicality rates for orange and grapefruit.

Table 2
Description of the entire food set.

Zucchini (slice)	Carrot (slice)	Tomato (quarter)	Bell pepper (quarter)	Eggplant (cube)	Beetroot (cube)
Green (T)	Orange (T)	Red (T)	Green (T)	Dark purple (T)	Purple (T)
Dark green (T)	Dark orange (T)	Dark red	Yellow (T)	Light purple	White
Light green	Yellow	Yellow	Red (T)	White	Pink
Yellow	Purple	Green	Orange	Green	Yellow

Apple (quarter)	Pear (cube)	Citrus fruit (slice)
Green (T)	Yellow (T)	Green (T)
Red (T)	Green (T)	Yellow (T)
Brown	Brown	Pink (T)
Yellow (T)	Red	Orange (T)

Note: (T) = typical color. The colors reported here are the skin colors of each fruit or vegetable.

Table 3
Characteristics of the three blocks of food pictures.

Block A	Block B	Block C
4 carrots (1)	4 zucchinis (2)	4 tomatoes (3)
4 bell peppers (4)	4 eggplants (5)	4 beetroots (6)
4 pears (2)	4 apples (1)	4 citrus fruits (3)

Note:The numbers in brackets are the typicality rankings for each type of vegetable and fruit.

the study was to understand how children perceived and categorized their food in the plate and to determine the factors that trigger rejections, we wanted to present them with food they actually can encounter in everyday life, for example in school canteens. In such settings, children encounter starters composed of beetroots cut in small cubes rather than whole beetroots for instance, and sometimes they don't know what the whole vegetable resembles.

The different foods were then cooked (but not peeled, as we wanted to retain the differences in colors) and photographed, controlling for contrast and luminosity. The visual stimuli were then printed separately on cards measuring 10 × 15 cm (see Appendix A for the 36 food pictures), and divided into three blocks of 12 pictures each (eight vegetable pictures and four fruit pictures per block; see Table 3).

Each block contained the same number of food items, cut in quarters, slices or cubes. For example, in Block A the four colored varieties of carrots were cut into slices, the varieties of bell peppers were cut into quarters, and the varieties of pears were cut into cubes. Moreover, in each block, the two kinds of vegetables differed considerably in typicality. Twelve additional stimuli, which were neither fruit nor vegetables, were used in a practice session (four pictures of cats, four pictures of dogs, and four pictures of cars, differing in terms of their overall colors).

2.3. Procedure

Children were tested individually for approximately 15 min in a quiet room at their school. They sat at a table, with the experimenter on their left side. There were three parts to the experiment, run successively and in a constant order for all the children.[10]

[10] It should be noted that the adult control group (Sample 1) only completed the first part of the study (forced sorting task).

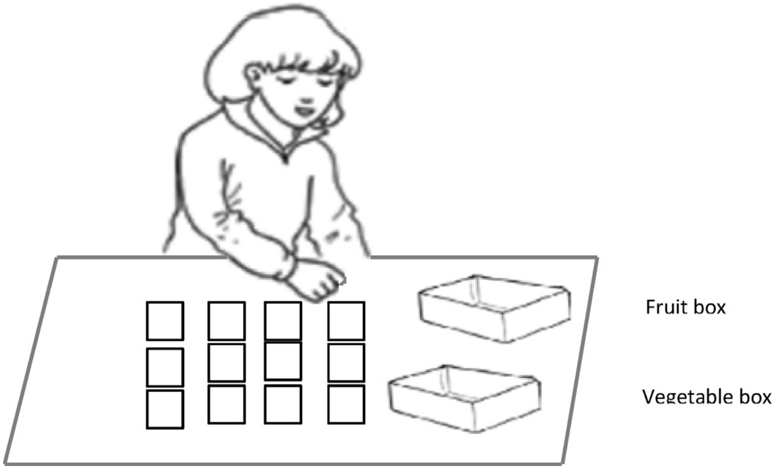

Fig. 1. Arrangement of cards on the table.
Note. This arrangement allowed the children to see all the pictures rapidly without having to make large exploratory eye or body movements. This drawing was realised based on illustrations from « Clic images 2.0 - Canopé académie de Dijon »: http://www.cndp.fr/crdp-dijon/clic-images/.

2.3.1. Part 1-Forced sorting task

The experimenter explained to the child that they were going to play a game with pictures and the rule was to sort them into two different boxes according to their categories. The game began with a familiarization phase where eight pictures of animals and four pictures of cars were shown simultaneously to the children (see Fig. 1). The experimenter explained that the child first had to find the animal pictures, and put them in the same box. Then the car pictures had to go in the other box. During this familiarization phase, the experimenter gave the children feedback and corrected their mistakes. Afterwards, the experimenter introduced the fruit and vegetable pictures, and asked the child to find the vegetable pictures first and put them in the same box, and then put the fruit pictures in the other box. Each child carried out this sorting task for two blocks of food pictures without any feedback from the experimenter. The order in which the pictures were placed on the table was randomized for each participant. Additionally, the order in which the blocks were provided was counterbalanced across participants (e.g., Participant 1 sorted blocks A and B, while Participant 2 sorted blocks A and C, etc.).

The experimenter recorded the type of response for each vegetable (hit or miss) and for each fruit (correct rejection or false alarm). We then assigned to each participant a hit score (i.e., number of cards placed in the vegetable box when the picture was a vegetable) and a false alarm score (i.e., number of cards placed in the vegetable box when the picture was a fruit). Hit scores could vary between 0 and 16, and false alarm scores between 0 and 8. Both these scores were important to take into account to evaluate children performances to the task. For example a child who would have placed the twelve pictures of block A in the vegetable box would have a high hit score (because she put in the right box all the vegetables from block A). However her categorization performances would be nevertheless poor as she would have put also all the fruit pictures from block A in the vegetable box and it will be indicated by a high rate of false alarms. Based on these two scores (hit and false alarm), we measured an index of discriminability (A′), and an index of the child's decision criterion (B″) (these indexes are widely used within the signal detection theory, see Grier, 1971; Stanislaw & Todorov, 1999). A′ ranged from 0 to 1, with 0.50 indicating responses at chance level, and 1 indicating maximum discriminability. B″ ranged from −1 to +1, with −1 indicating a liberal criterion (e.g., children tending to place cards in the vegetable box whatever the pictures), and 1 indicating a conservative criterion (e.g., children tending to place cards in the fruit box whatever the picture). Both indices were computed according to Grier's formulas (Grier, 1971): $A' = 1/2 + [(y - x)(1 + y - x)/4y(1 - x)]$, and $B'' = [y(1 - y) - x(1 - x)]/[(y(1 - y) + x(1 - x)]$ where y stood for the probability of a hit and x corresponded to the probability of a false alarm.

2.3.2. Part 2-Food rejection task

In the second part of the experiment, children were shown a third block of food pictures (arranged in a manner similar to that of the sorting task). In this task, children were asked to put the different foods they were unwilling to taste in the bin. The main objective of this task was to associate food rejection behaviors with performances on the sorting task. In order to make the test more tangible to the children, we used an actual small bin that was already present in the room and therefore familiar to them. For each child, the number and type of items placed in the bin was recorded by the experimenter.

2.3.3. Part 3- Color naming task

Following Macario (1991, Exp. 2 and 3)'s work, the last part of the experiment consisted of an examination of color naming abilities, so as to assess the potential relationship between color naming and the categorization of colored vegetables. Eleven monochrome pictures in colors extracted from the fruit and vegetable pictures (light green, dark green, light purple, dark

Table 4
Type of response and signal detection indices for each age group.

Age group	Hit percentage	False alarm percentage	discriminability A′	Decision criterion B″
2–4 years	73.4	44.0	0.72	−0.07
4–6 years	75.6	29.1	0.81	−0.05
adults	88.1	9.2	0.94	0.12

purple, red, dark red, yellow, orange, brown, pink and white) were printed separately on 5 × 5-cm cards and shown to the child. In a color-word production subtask, we asked the children to name each color. In a color-word comprehension subtask, we told the children the name of a color and asked them to point out the corresponding picture card. The order of the two subtasks was counterbalanced across children. For each subtask, we credited a child with knowing a particular color word if she produced or understood the correct color word (scoring 0 when the child did not know the color word and 1 when the child did know it). Note that, for the color-word production subtask children labeling the "light green" panel as just "green", or the "dark purple" panel as just "purple" were counted as correct responders. Each child could thus score between 0 and 11 on the word production subtask and on the word comprehension subtask. As scores on the two subtasks were closely correlated (as attested with Spearman's coefficient: $r = 0.70$, $p < 0.001$), we averaged these two scores. Each child was therefore assigned a single *color-word knowledge* score between 0 and to 11.

3. Results

3.1. Sorting task

To test the hypothesis that children's ability to perform categorization in the food domain improves with age, for each of the three age groups (2–4 years, 4–6 years, and adults), we assessed mean hit and false alarm responses, as well as A′ and B″ (results set out in Table 4).

3.1.1. Type of response

Overall, children had a high rate of hits ($M = 0.74$, $SD = 0.14$), and a moderate rate of false alarms ($M = 0.36$, $SD = 0.23$).

More specifically, the results set out in Table 4 indicate that the average hit rate for children aged 2–4 years was 0.73 ($SD = 0.08$), while the average hit rate for children aged 4–6 years was 0.75 ($SD = 0.15$). The adults performed better on the task, with higher hit rates ($M = 0.88$, $SD = 0.08$). An analysis of variance (ANOVA) on the percentage of hits, with age (3 groups) as a predictive variable, indicated an effect of age ($F = 11.94$, $p < 0.0001$). A post hoc LSD analysis revealed that hit rates for the two children's groups did not differ significantly, whereas there was a significant difference between the 2- to 4-year-old children and the adults ($p < 0.0001$), as well as between the 4- to 6-year-old children and the adults ($p = 0.0004$).

The mean false alarm rate for children aged 2–4 years was 0.44 ($SD = 0.14$), while the average false alarm rate for children aged 4–6 years was 0.29 ($SD = 0.23$). The adults performed better on the task, with lower false alarm rates ($M = 0.09$, $SD = 0.09$). A one-way ANOVA also indicated an effect of age ($F = 28.96$, $p < 0.0001$). More specifically, a post hoc LSD analysis revealed that false alarm rates differed significantly between the two children's groups ($p = 0.002$), as well as between the children and the adult participants ($p < 0.0001$ for 2–4 years vs. adults, and $p < 0.0001$ for 4–6 years vs. adults).

3.1.2. Discriminability A′

A′ for children was 0.77 (SD = 0.13; range = 0.50–1). Results (see Table 4) indicated that mean A′ for children aged 2–4 years was 0.72 ($SD = 0.11$), while the mean hit rate for children aged 4–6 years was 0.81 ($SD = 0.12$). The adults performed better on the task ($M = 0.94$, $SD = 0.04$). An ANOVA on A′ with age (3 groups) as a predictive variable indicated an effect of age ($F = 36.7$, $p < 0.0001$; Fig. 2). Post hoc LSD analysis revealed significant differences between the groups ($p = 0.002$ between the two children's groups, $p < 0.0001$ between the adults and younger children, and $p < 0.0001$ between the adults and older children).

To identify the variables that were most predictive of discriminability variation among the children, we carried out a stepwise procedure using the AIC[11] as our criterion for model selection. The predictive variables we retained were sex (boy/girl), age (younger/older), order of block presentation (AB/AC/BA/BC/CA/CB), food rejection (scores obtained to the CFRS questionnaire possibly ranging from 11 to 55) and exposure to fruit and vegetables (scores possibly ranging from 0 to 11). The first variables were discontinuous, and the last two continuous. This model significantly predicted discriminability variation across our sample ($p = 0.0003$) and explained 26% of this variation, as demonstrated by the adjusted R^2. It revealed effects of age ($F = 6.11$, $p = 0.016$) and rejection ($F = 4.99$, $p = 0.029$). As attested by post hoc LSD analyses, the older children performed significantly better than the younger children (see Fig. 2). Furthermore, the highly neophobic and picky children performed more poorly on the task than the less neophobic and picky children (see Fig. 3).

[11] The Akaike information criterion (AIC) is a measure of the relative quality of different statistical models. The retained model is usually the one with the lowest AIC (Hu, 2007).

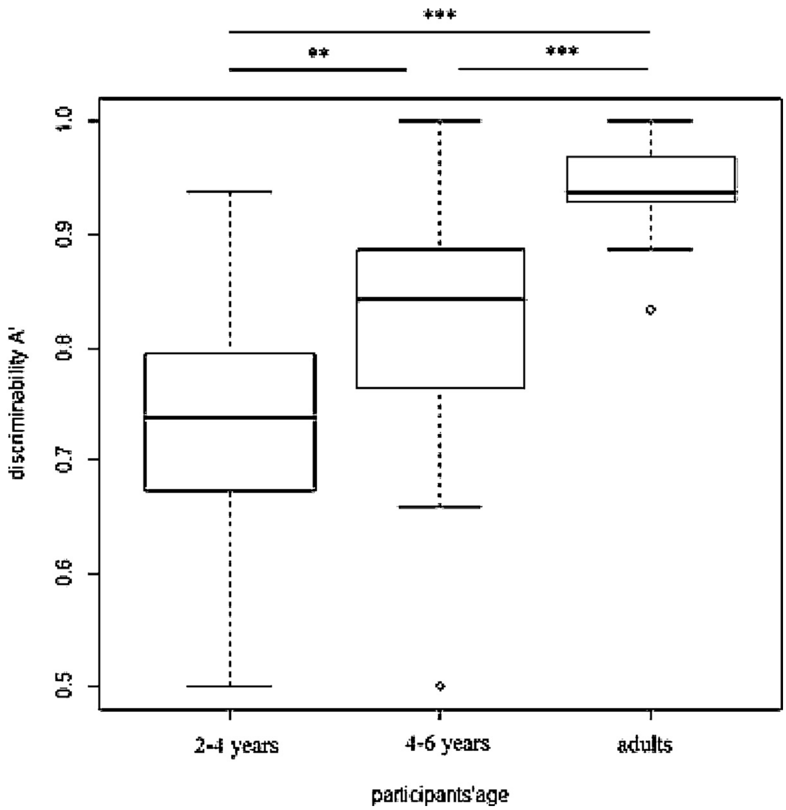

Fig. 2. Discriminability A′ for each of the age groups.
Note. Significant differences between the age groups are marked * for $p < 0.05$, ** for $p < 0.01$ and *** for $p < 0.001$.

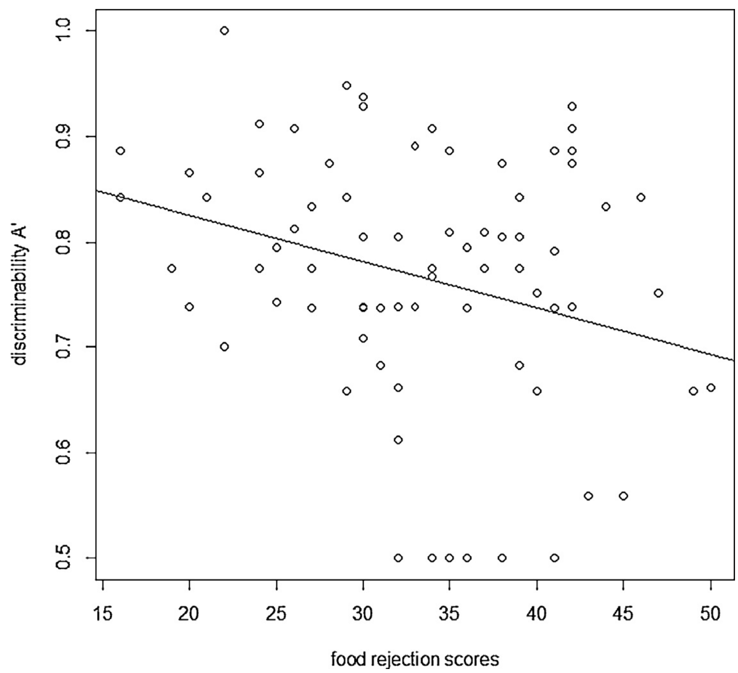

Fig. 3. Discriminability A′ as a function of children's food rejection scores.
Note. The Pearson coefficient correlation indicated a significant and negative correlation between the children's food rejection scores and discriminability A′ ($r = -0.27$, $p = 0.014$).

3.1.3. Decision criterion B″

The mean B″ for children was −0.06 (*SD* = 0.037; range = −1 to 1), meaning that overall, the children were neither liberal nor conservative in their responses. Results (see Table 4) indicated that the mean B″ for children aged 2–4 years was −0.07 (*SD* = 0.41), while the mean B″ for children aged 4–6 years was −0.05 (*SD* = 0.34). The adults' mean B″ was quite similar (*M* = 0.12, *SD* = 0.63), indicating that, like the children, they were neither liberal nor conservative in their responses. An ANOVA on B″, with age (3) as the predictive variable, did not indicate any age effect.

As with A′, to select the predictive variables that best explained variations in B″ across our child sample, we carried out a stepwise procedure using the AIC as the criterion for model selection. The sole predictive variable we retained was food rejection score (possibly ranging from 11 to 55). However, this model did not significantly predict variation in B″ ($p = 0.069$). Unlike A′, therefore, neither the children's characteristics nor the experimental setting affected B″.

3.1.4. Influence of A′ and B″ on food rejection scores

To test the hypothesis that food rejection is the behavioral consequence of an immature food categorization system, we conducted a regression analysis with A′ and B″ as predictive variables, and food rejection score obtained from the CFRS questionnaire as the predicted variable.[12] This model significantly predicted variation in the food rejection score across our child sample ($p = 0.019$), but explained rather a low proportion (7.5%) of this variability, as demonstrated by the adjusted R^2. Results revealed an effect of A′ on food rejection scores ($F = 4.79$, $p = 0.031$). This effect indicated that children who performed poorly on the sorting task were more neophobic and picky than children who performed well on it (see Fig. 2).

3.2. Food rejection task

Spearman's correlation coefficients failed to reveal any significant correlation between the number of pictures binned during the food rejection task and either children's food rejection scores obtained from the CFRS questionnaire ($r = 0.06$, *ns*) or their fruit and vegetable exposure scores ($r = 0.10$, *ns*). To assess the potential influence of picture characteristics on the decision to place them in the bin, we ran an ANOVA (with post hoc LSD analysis) on the binning percentage for each picture, with category (2), shape (3), color (11) and color typicality (2) as predictive variables. This model did not significantly predict the proportion of times a picture was binned and did not reveal any effect of picture characteristics.

3.3. Color naming task

Overall, children were quite familiar with the names of the colors of the 11 color pictures they were shown. The children's mean color name score was 8 (*SD* = 1.48; range: 3–11). Their color name knowledge varied according to age, as attested by the Mann-Whitney test between the two age groups ($W = 226.5$, $p < 0.0001$), but not according to sex ($W = 693$, $p = 0.53$). Moreover, the children's color name knowledge was not correlated with their food rejection scores (as attested by Spearman's coefficient, $r = -0.09$, *ns*).

3.4. Categorization performance based on vegetable characteristics

To test the hypothesis that, in food categorization, color is important mainly because of the information it conveys about the typicality of a given food exemplar, we calculated the percentage of hits for each vegetable across the children (see Appendix A). To assess the potential influence of each vegetable's characteristics on the decision to categorize it as a vegetable, we ran an ANOVA (with post hoc LSD analysis) on the percentage of hits for each vegetable across children, with shape (3), color (11), color typicality (2) and vegetable kind typicality (6) as predictive variables. This model significantly predicted variations in the percentage of hits for vegetable pictures among children ($p = 0.002$) and explained 76% of this variability, as demonstrated by the adjusted R^2. Results indicated a color typicality effect ($F = 6.99$, $p = 0.024$), and a color effect ($F = 4.1$, $p = 0.01$). As shown in Fig. 4, typically colored vegetables were significantly better categorized than atypically colored ones (hit percentage 81.6% vs. 69.3%).

Concerning the color effect, yellow, white and pink vegetables were poorly categorized (see Fig. 5), compared with, red, orange and dark green vegetables. However, post hoc LSD analysis revealed that none of the colors was significantly less well recognized as a potential color for vegetables.

4. Discussion

The present study had a threefold aim: (i) investigate 2- to 6-year-old children's ability to distinguish between fruit and vegetable items in a categorization task; (ii) find evidence for the putative relationship between food rejection and food

[12] A′ represented children's sensitivity to stimulus differences, that is to say, their ability to distinguish between fruit and vegetables in the present experiment (MacMillan & Creelman, 2005). By contrast, B″ reflected their leaning toward one response or the other, that is to say, their inclination to favor the vegetable box over the fruit box in the present experiment (MacMillan & Creelman, 2005). These indices therefore captured the degree of maturity of their food categorization system and the types of classification strategy that might be involved.

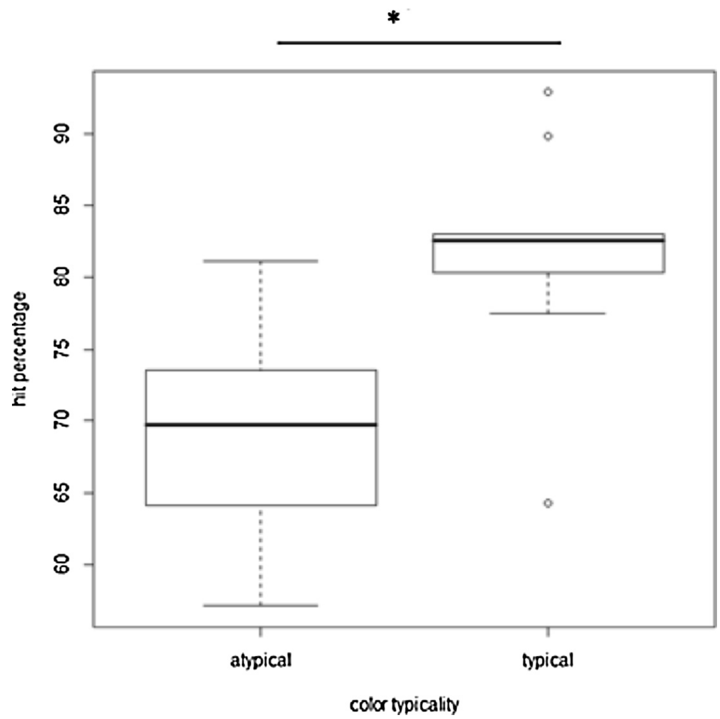

Fig. 4. Hit percentages for atypically and typically colored vegetables. *Note.* *$p < 0.05$, **$p < 0.01$.

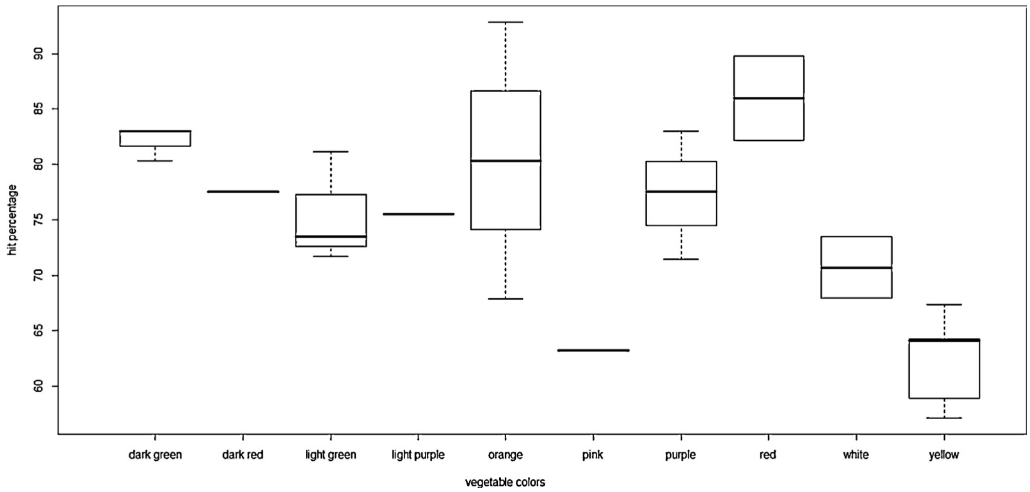

Fig. 5. Hit percentage for each vegetable color.

categorization performance in young children; and (iii) shed light on the mechanisms behind the central role of color in food categorization. To our knowledge, it was the first study to investigate the potential relationship between food rejection and the typical development of the food categorization system, as well as the first attempt to examine the role of color typicality in children's food categorization.

4.1. Do children's food categorization performances improve with age?

Results indicated that children as young as 2 years were able to distinguish fairly efficiently between different food categories (mean discriminability for 2- to 4-year-olds: 0.73), even with complex food stimuli that varied in shape and color. This result proved that our methodology was appropriate for this age range, and extended the findings reported by Nguyen and Murphy (2003), who reported that children can acquire both fruit and vegetable taxonomic categories as early as 3 years. However, while the younger children (2–4 years) displayed a high rate of hits (73%), they also displayed a high rate of false alarms (44%). As Cashdan pointed out (1994), this meant that their food categorization system was rather crude and still under construction. Results also indicated a clear developmental effect. The children's ability to correctly categorize items on the basis of their basic visual properties increased with age. While both younger and older children had hit rates of around 0.74, there was a clear and significant fall in the mean false alarm rate for older children (0.44 for 2–4-year-olds vs. 0.29 for 4–6-year-olds). Consequently, discriminability was greater at 4–6 years (as shown in Fig. 2), suggesting that categorization abilities improve between the ages of 2 and 6 years. This finding is consistent with previous studies of food categorization development in children (see Bovet et al., 2005; Nguyen & Murphy, 2003). However, the food categorization system was still under construction at 4–6 years, as attested by the adults' significantly better performances (both hit and false alarm rates were significantly higher for adults, and consequently discriminability as well). As food taxonomic categorization does not take place solely at a perceptual level (where items are classified according to their physical resemblance), but rather at a conceptual level (where items are classified according to functional or conceptual knowledge, with little perceptual resemblance between category members; Rosch & Mervis, 1975; Tomikawa & Dodd, 1980), we can assume that the children had not yet completely developed taxonomic categories within the food domain and mostly used perceptual cues to categorize items.

Across the children, we did not observe a clear response bias toward one answer ("It's a vegetable") rather than another ("It's a fruit"), as attested by a mean B″ of −0.06. Moreover we failed to observe any changes with age: no difference in mean B″ between either the two age groups (2–4 and 4–6 years) or the children and adult controls. As a consistent pattern was found in adults and children, we can reasonably rule out the possibility that children's responses in our study were elicited by the mere presence of the experimenter and social desirability effects, as can be the case in studies with young children (Lavin & Hall, 2001).

4.2. Is food rejection the behavioral consequence of an immature food categorization system?

Our findings showed that children's food rejection scores and sorting task performances were significantly correlated (Pearson's correlation coefficient: $r = -0.27$, $p = 0.014$; see Fig. 3). Further statistical analyses indicated that highly neophobic-picky children performed more poorly than the other children on the sorting task (as attested by the retained model predicting A′ variation among children), suggesting that the children's level of food rejection partly predicted their performance on the fruit and vegetable categorization task. From this perspective, we could argue that food neophobia and pickiness acted as restraining factors on food discriminability, that is to say, they behaved as dampers on the development of the food categorization system. At a given age, strongly neophobic and picky children will thus have poorer food category content than other children, because they do not accept new items in the food category as easily and have fewer learning opportunities with food categories. Indeed caregivers of children who display high food rejection tendencies, are often discouraged to present fruit and vegetables to their children (Heath, Houston-Price, & Kennedy, 2011), leading to fewer experiences and it is known that children's categorization abilities differ as a function of their experience (Chi, Hutchinson, & Robin, 1989). This claim was supported by the fact that neophobic-picky children performed the same as the younger children in terms of hit and false alarm rates (mean hit and false alarm rates for neophobic-picky children: 0.76 and 0.41). Furthermore, the non-neophobic-picky children performed just as well as the older children in terms of hit and false alarm rates (mean hit and false alarm rates for non-neophobic-picky children: 0.77 and 0.31). These results were especially striking, given that food rejection scores were not correlated with age.

Statistical analyses also revealed that children with a poor ability to distinguish between fruits and vegetables (i.e., low A′) tended to be more neophobic and picky than the children with high discrimination abilities (as attested by the model predicting variations in food rejection scores across children). This additional finding indicated that children's discrimination abilities were predictive of their level of food rejection, thus supporting the premise that food rejection is partly the behavioral consequence of an immature food categorization system (Brown, 2010; Lafraire et al., 2016). This finding possibly accounts for the recognized positive effect of visual food exposure on food rejection and attitudes towards food (Birch, McPhee, Shoba, Pirok, & Steinberg, 1987; Birch & Fisher, 1998). Exposure would facilitate the recognition process (Lafraire et al., 2016; Zajonc, 1968), by enriching food category content and food prototypes and therefore reduces the probability that food items will not be judged as food category members because they are not close enough to the food prototype.

Finally, we could be facing a vicious circle: food rejections seem to be the behavioral consequences of a developing categorization system. Consequently, caregivers may be discouraged to present fruit and vegetables to their children, leading to fewer learning opportunities and to hinder the development of the food categorization system. Focusing on conceptual development could then be an efficient manner to tackle food rejections behaviors as demonstrated by a recent study from Gripshover and Markman (2013). Indeed, in their research they compared usual educational programs about nutrition to a *knowledge based-approach* nutritional education program (which provided children with a rich conceptual framework about food) and found that, children who attended to the latter program ate more vegetables at snack time.

However, contrasting with these promising results linking food rejection to categorization development in children, scores on the food rejection scale were not correlated with their binning behaviors, leading us to conclude that, contrary to parental reports, the food rejection task was not a relevant measure for associating food rejection behaviors with sorting performances. Two main reasons may explain this negative result. First, this task was often regarded as a game by the children, as they were allowed to thrown food away-a behavior banned in the school canteen. Moreover, some of the comments made during this task by nursery staff indicated that the children did not display their normal food rejection behaviors (e.g., while one child was throwing away almost all the pictures into the garbage, a staff member told the experimenter that this child usually ate nearly everything). Secondly another reason to have some doubt regarding the reliability of the binning behaviors as an appraisal of the food rejection behaviors is that, we assessed the predictive validity of the food rejection questionnaire in a previous study (Rioux et al. submitted) and found that caregivers were relevant predictors of their children's behaviors toward foods.

4.3. Is color important because it conveys information about the typicality of a given food item?

Our results replicated Macario's findings (1991) about the importance of color in food categorization. Indeed, contrary to shape, color information was a salient variable predicting the hit percent of a given vegetable (as attested by the model we retained predicting the variation in the hit percentage across vegetables). Possibly explaining this result is that within the food domain, shape usually changes across serving and recipes for a given food item, while color is a more constant feature.

Results also indicated that colors are important in food categorization mainly because they convey information on typicality. Indeed, among the children, color typicality was the most salient variable predicting the hit percentage of a given vegetable (as attested by the model we retained predicting the variation in the hit percentage across vegetables). Moreover, the effect of color *per se* described above may also have been partly explained by typicality. Yellow, pink and white vegetables were the least well recognized vegetables (i.e., lowest hit percentages for these vegetables; see Appendix A). Interestingly, in our vegetable sample (carrots, tomatoes, eggplants, beetroots, bell peppers and zucchinis), white, pink and yellow were the only colors that were never typical for a given vegetable (compared with dark green, red or orange, for example, which were typical for zucchinis, tomatoes and carrots).

Concerning the color naming task, we did not replicate Macario's finding (1991, Exp. 3), which associated children's ability to name colors with their discrimination of anomalously colored objects, as we failed to find any significant correlations between color name knowledge and sorting task performances across children. However, as even young children were quite familiar with color names (mean color name knowledge for the youngest group of children: 7/11), it was maybe not possible to distinguish between children on this basis. Moreover, some comments made during this task by nursery staff indicated that the very young children often did know almost every color they were shown, but were too shy or intimidated by the experimenter to name them (it should be recalled that this was the only part of the experiment where the children had to talk), thereby artificially lowering their color knowledge scores.

4.4. Conclusion and perspectives

In conclusion, our results validated the three experimental hypotheses, by providing evidence in favor of (i) an improvement in children's food categorization abilities from the age of 2–3 years, (ii) a negative correlation between food rejection and food categorization performances in young children; and (iii) the central role of typicality in explaining the importance of color in food categorization.

Nonetheless, our study had several limitations. First, we did not control for color preferences or fruit/vegetable preferences, whereas Carey (2009) and Murphy (2002) pointed out that a priori preferences for one of the categories tested in categorization task should be assessed. Second, color typicality was assessed by an external sample of 10 adults, rather than by the children themselves. In future, it would be worthwhile assessing children's preferences and opinions about color typicality. When children are as young as 2 years, it is rather difficult to ask them directly if they think that a color is typical for a given vegetable, as we did for adults. It might therefore be helpful to implement a puppet procedure (e.g., Lavin & Hall, 2001), by asking children to describe a tomato to a puppet that does not know what it is, and noting which colors the children use to describe it. Third, the blocks of food pictures contained different numbers of typically and atypically colored food items, as we used real fruit and vegetables for our stimulus sample and were therefore constrained by the availability of fruit and vegetable varieties at the time of the experiment. It would thus be interesting to balance typically and atypically colored food items more evenly in future experiments testing this effect on children's food categorization.

Despite these limitations, we believe that the present experiment opened up promising new avenues of research, and shed light on the cognitive mechanisms underlying different kinds of food rejection (neophobia and pickiness), as well as on the central role of color in food categorization processes. However these are only preliminary conclusions and more research is needed to gain a better understanding of the mechanisms that come into play. For instance, it will be of interest to investigate children categorization performances with other food categories that are less prone to rejections (such as starchy foods) and investigate whether the negative correlations between categorization performances and food rejections scores continue to exist. Another line of research would be to investigate category-based induction in children in relation to their level of food rejection. As it is often stated that "one important function of categories is to allow inferences that extend beyond surface appearances" (Gelman & O'Reilly, 1988, p. 876) and highly neophobic and picky children in our study performed poorly on the food categorization task, category-based induction and food rejections scores may as well be correlated. Finally, it would be worth exploring the effect of visual food exposure (in an ecological setting such as a school canteen, where food rejection behaviors are commonly observed) on pupils' attitudes towards foods in the light of the present experiment's results. If food rejection acts as a damper on the development of the food categorization system, and if exposure to food variety (foods differing in color, shape, texture, etc.) enriches food category content and facilitates the recognition process (Lafraire et al., 2016), highly neophobic-picky children with weak discriminability and recognition abilities should greatly benefit from this type of exposure.

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Appendix A.

Color photographs of the 36 pictures and hit or false alarm rate for each of them. Hit rates concern the vegetable pictures and false alarm rates concern the fruit pictures.

Block A			
Dark purple carrot Hit rate : 71.4 	Orange carrot Hit rate : 92.5 	Orange carrot Hit rate : 80.3 	Yellow carrot Hit rate : 58.9 
Orange bell pepper Hit rate : 67.8 	Yellow bell pepper Hit rate : 64.2 	Red bell pepper Hit rate : 82.1 	Dark green bell pepper Hit rate 80.3 
Light green pear False alarm rate : 58.9 	Red pear False alarm rate : 44.6 	Brown pear False alarm rate : 44.6 	Yellow pear : False alarm rate : 39.3 

Block B			
Light green eggplant Hit rate : 81.1 	Light purple eggplant Hit rate : 75.5 	Dark purple eggplant Hit rate : 83.0 	White eggplant Hit rate : 67.9 
Yellow zuchini Hit rate : 64.1 	Dark green Zuchini Hit rate : 83.0 	Light green zuchini Hit rate : 71.7 	Dark green zuchini Hit rate : 83.0 
Red apple False alarm rate : 13.2 	Brown apple False alarm rate : 17.0 	Yellow apple False alarm rate : 30.2 	Light green apple False alarm rate : 35.8 

Block C			
Red tomato Hit rate : 89.8 	Dark red tomato Hit rate : 77.5 	Light green tomato Hit rate : 73.5 	Yellow tomato Hit rate : 57.1 
Pink beetroot Hit rate : 63.2 	White beetroot Hit rate : 73.5 	Yellow beetroot Hit rate : 67.3 	Dark purple beetroot Hit rate : 77.5 
Yellow lemon False alarm : 32.5 	Dark green lime False alarm : 71.4 	Red grapefruit False alarm rate : 30.6 	Orange False alarm : 20.4 

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Chapter 7. Food rejection and the development of food category-based induction in young children

This chapter focuses on the investigation of the relationships between category-based induction development in young children and their food neophobia and pickiness.

Research on category-based induction has widely used property generalization paradigms similar to the paradigm developed by Gelman and Markman (1986): a property is associated with a target picture, and children are asked to select among different items (e.g., a taxonomically target-related, a thematically target-related, a perceptually target-related etc.) the item which also possesses the property. Past research has found evidence of children's inductive selectivity using this technique (for instance children make more biochemical inferences for the taxonomic categories than for the script categories; Nguyen & Murphy, 2003).

To investigate children category-based inductive reasoning a similar paradigm was therefore used. Only two items were presented to children (besides the target item), to adapt this paradigm to the young study population: a taxonomically target-related item and a perceptually target-related item.

Taxonomic relation was chosen for the first test item, because children preferentially rely on taxonomic categories when reasoning about the effects of eating and to represent bio-chemical knowledge (vitamins, toxic secondary compounds etc., Thibaut, Nguyen and Murphy, 2016). Eggs and cereals are both likely to appear at breakfast (script relation) but their nutritional profiles differ (Thibaut et al., 2016).

Perceptual relation was chosen for the second test item, because children with immature induction system are likely to focus on perceptual similarities when making induction (Sloutsky & Fisher, 2004).

Finally, the property to be generalized was a biological property. This kind of property was chosen because, from 3 years of age, children generalized biological properties like *has pectin inside* of an instance of vegetable to other members of the taxonomic category (Gelman, 1988; Nguyen & Murphy, 2003). Additionally, a biological property was chosen because most benefits and problems associated with foods are based on their bio-chemical composition.

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Food rejection and the development of food category-based induction in 2–6 years old children

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ABSTRACT
We studied children's inductive inferences within the domain of food categories. There has so far been little research on inductive reasoning about food among children, despite the theoretical and practical importance of knowing what knowledge children bring to the table and how they use it. We tested the hypotheses that children's food category-based induction performances and their food rejection are negatively correlated, and that these performances are influenced by the colour typicality of the food items. We recruited 126 children aged 2–6 years, and administered a category-based induction task. Participants were successively shown 8 sets of three pictures containing one target picture (a vegetable) and two test pictures (a vegetable dissimilar in colour to the target picture and a fruit similar in colour to the target picture). For each set, participants were told a novel property about the target picture and asked to generalise this property to one of the two test pictures. Additionally, the parents of each child filled out a questionnaire about his or her food rejection tendencies. Results on accuracy (i.e. if participants generalised the properties according to category membership, not perceptual similarity) provided the first empirical evidence in favour of a negative relationship between children's food rejection and food category-based induction.

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Introduction

Category-based induction is a central process underlying much of our reasoning in everyday life (Hayes, 2007; Murphy, 2002; Smith & Medin, 1981). For example, at lunchtime, children will pick carrots as a side from the school cafeteria buffet because they know that carrots are vegetables. Even if they have never seen a particular variety of carrot before, they can infer its properties (e.g. tasty, satisfying) from their knowledge of the *carrot* or *vegetable* category. By allowing us to disregard insignificant perceptual differences (size, colour etc.), categories enable us to take advantage of our past experiences and to generalise our knowledge to new instances or new situations, thereby avoiding the need to examine each and every object or situation de novo (Gelman & Markman, 1986; Murphy, 2002; Murphy & Ross, 1999).

The majority of recent research has focused on the process by which category-based inferences are drawn (Fisher, Godwin, & Matlen, 2015a; Gelman & Davidson, 2013; Sloutsky, Deng, Fisher, & Kloos, 2015). The present study addressed one specific issue of how these inferences are drawn, namely we explored the role of individual differences (e.g. in food rejection behaviours) in children's induction within the domain of food categories. So far, there has been little focus on food induction among children, despite the theoretical and practical importance of knowing what knowledge children bring to the table and how they use it. At the theoretical level, children's performances on food category-based induction tasks reflect the way they acquire new knowledge about nutrition and edibility. Moreover, several research studies argue in favour of certain food domain specificity effects. For instance, adults and children attend mainly to shape information when viewing artifacts, but attend to colour or texture information when viewing foods (Foroni & Rumiati, in press; Foroni, Pergola, & Rumiati, 2016; Lavin & Hall, 2001; Macario, 1991; Shutts, Condry,

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Santos, & Spelke, 2009). Additionally, a recent neuropsychological review on food representations reporting how brain-damaged patients recognise food and nonfood items, suggested that representations of foods dissociate from representations of animals or other living things (Rumiati & Foroni, 2016). More precisely, using for instance a word-to-picture matching task, Rumiati, Foroni, Pergola, Rossi, and Silveri (2016) showed that both natural and manufactured food tended to be processed better than non-foods in patients with Alzheimer dementia or primary progressive aphasias. At the practical level, it is important that we understand the relationship between food behaviours (e.g. food rejection disposition) and cognitive development (e.g. development of category-based induction) if we are to design efficient education programmes aiming at promoting healthier eating behaviours (Thibaut, Nguyen, & Murphy, 2016). This is especially crucial given the widening gap between children's actual consumption of fruit and vegetables and the recommended intake needed for normal and healthy development (Cockroft, Durkin, Masding, & Cade, 2005).

Development of food category-based induction and sensitivity to individual differences

There is much evidence showing that young children intuitively focus on perceptual similarities when making induction (i.e. children draw many inferences from one item to a perceptually similar item and few inferences from one item to a perceptually dissimilar item) and maintain this focus until they have developed the knowledge base necessary to support the shift toward a focus on category membership (Badger & Shapiro, 2012; Fisher et al., 2015a; Sloutsky & Fisher, 2004; Sloutsky et al., 2015; but see Gelman & Coley, 1990; Gelman & Davidson, 2013; Gelman & Markman, 1986, 1987 for diverging evidences and counterarguments). For example, in a study conducted by Chi, Hutchinson, and Robin (1989) where children were presented with unknown exemplars of dinosaurs, children who had prior knowledge about dinosaurs tended to make taxonomic category-based inferences (e.g. a child said that a novel exemplar of a dinosaur labelled *duckbill* was probably "a good swimmer because *duckbills* are good swimmers"). By contrast, novices were likely to make inferences based on a salient perceptual feature of the exemplar (e.g. a child said that a novel exemplar of dinosaur labelled duckbill "could probably walk real fast because *he has giant legs*").

Prior knowledge of a particular domain is acquired mainly through experience and learning. Within the food domain, preschoolers have extremely diverse experiences and learning opportunities that could well influence their inductive performances in this domain. Precisely, the two main kinds of food rejection in children, *food neophobia* (defined as the reluctance to eat novel food items; Pliner & Hobden, 1992) and *pickiness* (defined as the rejection of substantial amounts of familiar foods, and rejection of certain food textures; Taylor, Wernimont, Northstone, & Emmett, 2015), contribute to narrowing children's dietary variety and reducing their experiences with fruit and vegetables (Carruth, Ziegler, Gordon, & Barr, 2004; Cashdan, 1998; Dovey, Staples, Gibson, & Halford, 2008; Falciglia, Couch, Gribble, Pabst, & Frank, 2000; Heath, Houston-Price, & Kennedy, 2011; Lafraire, Rioux, Giboreau, & Picard, 2016).

A relationship between children's food rejection behaviours and their cognitive performances in the food domain was uncovered in a recent study. Using a forced-sorting task involving exemplars of the fruit and vegetable categories, Rioux, Picard, and Lafraire (2016) showed that, at a given age, highly picky and neophobic children displayed poorer categorisation performances than their non-picky and neophilic peers. More precisely, categorisation performances were roughly equivalent for 2–4 years old children and highly picky-neophobic children, while categorisation performances were roughly equivalent for 4–6 years old children and low picky-neophobic children. These results were especially striking, given that food rejection scores were not correlated with age. Rioux et al. (2016) then hypothesised that food rejections could arise because of a miscategorisation of food items and could be partly seen as the behavioural consequences of an immature categorisation system.

"One important function of categories is to allow inferences that extend beyond surface appearances" (Gelman & O'Reilly, 1988, p. 876), it is therefore possible that neophobic and picky children, who fail to categorise certain food items, focus preferentially on superficial appearances to generalise knowledge (and maintain this focus until they have developed the conceptual knowledge allowing a shift toward a focus on category membership, Badger & Shapiro, 2012; Fisher et al., 2015a;

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Sloutsky et al., 2015; Sloutsky & Fisher, 2004). For example, if a highly neophobic and picky child believes that the round and red tomatoes served at home are edible, will he/she infer that a new tomato served at the school cafeteria is also a tomato, if it differs in shape, texture, colour, or even mode of presentation? We would expect that, as young children, highly picky and neophobic children will use more perceptual similarity (rather than category membership) to draw inductions compared to children with a low level of food rejection. So far, however, at least to our knowledge, this assumption has never been tested.

Importance of color in food induction

Most studies investigating induction mechanisms and development within real-world categories have used paradigms where taxonomic category membership is pitted against overall perceptual similarity. As far as we are aware, only a handful of studies have assessed the role of the similarity of a specific feature, while within the food domain, the features that potentially influence children's food selection need to be further investigated alongside certain individual characteristics. In particular, if highly neophobic and picky children are likely to make inferences based on a salient perceptual feature instead of category membership, it is important to know which feature they will primarily attend to.

One important finding in the food domain is that children from the age of 2 years old attend to information about colour, rather than shape, when discriminating between edible and inedible substances or between different kinds of foods (Lavin & Hall, 2001; Macario, 1991; Shutts et al., 2009). This finding seems at odd with the literature on the *shape bias* that put forward that preschoolers usually match two or more objects on the basis of shape (Landau, Smith, & Jones, 1988; Yoshida & Smith, 2003).

Recent findings (Rioux et al., 2016) however indicate that, in the food domain, colour is important because it conveys information about typicality (unlike shape, which usually changes across servings and recipes). In the study by Rioux et al., children were presented with fruit and vegetables that differed in shape, colour, or colour typicality, and asked to sort them according to category. Rioux and colleagues found that colour typicality was the most salient variable, predicting whether or not food items would be correctly categorised. As typicality is an important determinant of category-based induction (i.e. a novel property involving typical exemplars of a category is believed to apply to other members of the category, whereas a premise about atypical exemplars is more narrowly generalised to other members; Dunsmoor & Murphy, 2014; Murphy, 2002), it would be useful to investigate the role of colour similarity and typicality (rather than overall similarity) in children's food inductive inferences. For example, if children believe that typical red tomatoes are edible, will they infer that atypical green tomatoes are also edible, and vice versa? Additionally, if highly neophobic and picky children are likely to make inferences based on colour similarity instead of category membership, is colour typicality a more salient feature for these children?

The present study

To summarise, we designed the present study to determine whether and how children's induction performances within the domain of food vary according to individual characteristics (e.g. food rejection disposition) and food item characteristics (e.g. colour typicality). We conducted a property generalisation task, when perceptual and categorical pieces of information were pitted against each other, as in the seminal study by Gelman and Markman (1986), with children from 2 to 6 years of age. We chose fruit and vegetable categories because by the age of 2–6 years, children have usually encountered several exemplars of these foods and have developed the corresponding taxonomic categories (Nguyen & Murphy, 2003). Fruit and vegetables were also chosen because they are likely to be rejected by children in this age range, and are usually available in different colours. Importantly, we manipulated the colour typicality of the vegetables used as target and test items in our picture sets, so as to test the impact of colour typicality on children's performances on a property generalisation task. Finally, as in Gelman and Markman's study (1987), we used three separate conditions, where participants could either see the pictures *and* hear the labels (word-and-picture condition), just see the pictures (picture-only condition), or just hear the labels (word-only condition). By varying what information is available to children, we can determine on what bases children draw inferences and whether the information used is influenced by individual differences, namely food

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rejection disposition. Compared to the *word-and-picture* condition, the *picture only* condition draw children's attention to information conveyed by perceptual cues (i.e. both category and perceptual information). The *word-only* condition draw children's attention to the information conveyed by labels (i.e. only category information). In this latter condition, as no perceptual cues are available, no difference should appear between highly neophobic children and non-neophobic children.

Our main hypotheses were as follows:

(1a) Children with high food rejection dispositions will focus on colour similarities (instead of categorical membership) to draw induction within the food domain.
(1b) Difference between highly neophobic children and non-neophobic children will be greater in the condition where both categorical and colour information is given (*word and picture* and *picture-only* conditions) compared to the condition when only categorical information is given (*word-only* condition).
(2a) Atypically coloured food items will be more liable to induction errors than typically coloured food items.
(2b) Difference between highly neophobic children and non neophobic children will be greater in the triad with atypically coloured food items compared to the triad with typically coloured food items.

Method

Participants

The participants were 126 children (63 girls and 63 boys; age range = 24–82 months; mean age = 51.4 months, *SD* = 11.9). They were all pupils at preschools in the Paris or Lyon urban area (France). They were predominately Caucasian and came from middle-class communities. An additional (control) group of 30 young adults recruited from the universities of Aix-Marseille and Lyons (France) also took part in the study.

Prior to the study, the parents of each child filled out a questionnaire about his or her food rejection disposition. We used the Child Food Rejection Scale (CFRS; Rioux, Lafraire, & Picard, 2017) for this purpose. The CFRS was developed to assess food rejection disposition in children aged 2–7 years, and includes two subscales: one is measuring children's food neophobia (6 items) and one is measuring their pickiness (5 items). Scores can range from 11 to 55 with high scores indicating high food rejection dispositions (both high neophobia and pickiness). Parents were also asked to indicate whether or not their child had been exposed to each of the fruit and vegetable exemplars used in the experiment (6 different fruits or vegetables were used; thus exposure score possibly ranging from 0 to 6).

Materials and procedure

Materials

The materials consisted of colour photographs of real fruit and vegetables, controlled for contrast and luminosity. There were 8 triad sets in total, each set containing three pictures: one target picture and two test pictures. Each triad set was printed on a laminated card measuring 21 × 29.7 cm. As existing studies on category-based inferences (Fisher, Godwin, Matlen, & Unger, 2015b; Fisher, Matlen, & Godwin, 2011; Gelman & Markman, 1986) in each set, one of the test pictures (*Test picture 1*) belonged to the same taxonomic superordinate category as the target picture, but was perceptually dissimilar, while the other test picture (*Test picture 2*) belonged to a different taxonomic superordinate category from the target picture, but was perceptually similar (see Figure 1). The main difference between the present study and previous studies of category-based inferences with natural kinds was the focus on (i) food categories and (ii) colour similarity instead of overall perceptual similarity (including shape, colour, size etc.).

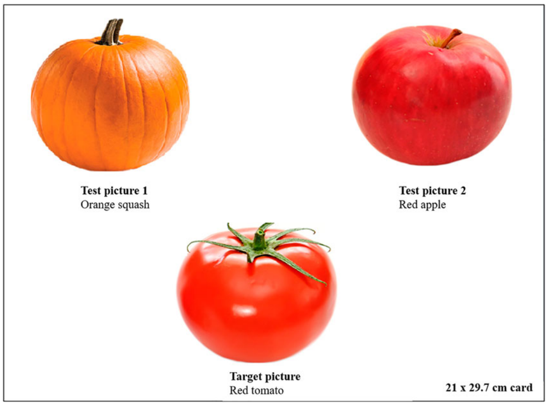

Figure 1. Example of a triad of pictures used in the property generalisation task.

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Because vegetables are extremely prone to food rejections, in the present study we were particularly interested in the way children generalise knowledge to new vegetables, therefore, the target picture was always a vegetable. Test picture 1 was another vegetable dissimilar in colour to the target, while Test picture 2 was a fruit similar in colour to the target. This is illustrated in Figure 1, where the target picture is a red tomato (vegetable), Test picture 1 is an orange-colored squash (another vegetable, but with a dissimilar colour), and Test picture 2 is a red apple (a fruit, but similar in colour to the target). As the emphasis was put on colour, all of the pictures in a given set were similar overall in shape and size.

To generate our trial set, we first visited a school cafeteria to see which fruits and vegetables were frequently served to children, and therefore familiar to them. On this basis, we selected four vegetables (carrot, tomato, squash and zucchini) and two fruits (apple and banana) that were commonly served and were available in different colours (according to caregivers' report and exposure scores, each of these fruits or vegetables were consumed at home by more than 82% of the children). For each vegetable, we chose two varieties that differed in colour (either *typically coloured* or *atypically coloured*). Colour typicality was assessed based on results from a pretest in which we asked 10 adults to rate the typicality (either *typical* or *atypical*) of the colours chosen for each vegetable. The different foods pictured are shown in Table 1.

We selected two of the four chosen vegetables as targets: tomatoes (red and green), and zucchini (purple and yellow). To avoid any confounding effect of a particular shape, we used both a round and a long-shaped vegetable as target. The two other chosen vegetables were used as Test pictures 1: carrots (orange and purple) and squashes (orange and white). The two fruits served as Test pictures 2: apples (red and green) and bananas (yellow and green). The full set of triads is shown in Table 2. As can be seen from this table, each target food was presented two times and was always paired with the same Test picture 2 (different category, but similar colour). The red tomato was therefore always paired with the red apple, the green tomato with the green apple, the green zucchini with the green banana, and the yellow zucchini with the yellow banana. Test picture 1 (same category, but dissimilar colour) varied across the two presentations, and could be (i) a different vegetable from the target and typically coloured (see Figure 1), or (ii) a different vegetable from the target and atypically coloured.

The present study design differs from existing studies on category-based induction because the same target picture was presented several times. This design was chosen because we were particularly interested in the colour typicality effect (and not the kind typicality) and it was therefore important to maintain constant the target picture while varying Test pictures 1 in term of colour typicality. Additionally the design differs from existing studies because we used the same color-match fruits two times (across the two presentations of a given target picture). This was mainly due of practical reason. Indeed because we worked with ecological stimuli and familiar food items it was not possible to find enough familiar color-matched fruits.

Two additional sets containing pictures of animals were used in a training session. In these two sets the target picture was a dog that "had an organ called a vesibule". Test picture 1 was another dog dissimilar in overall shape and colour, while Test picture 2 was a cat similar in overall shape and colour.

To make sure that the pictures we thought were more perceptually similar (because they shared the same colour) were indeed perceived of as such by participants, we asked the control group of 30 young adults to rate the perceptual similarity of

Table 1. Description of all the food items (based on school cafeteria observations).

Carrot	Tomato	Squash	Zucchini	Apple	Banana
Orange (T) Purple (A)	Red (T) Green (A)	Orange (T) White (A)	Green (T) Yellow (A)	Red Green	Yellow Green

Note: (T) = typically coloured; (A) = atypically coloured. The colours reported here are the skin colours of each fruit or vegetable, and in the pictures, the food items were shown uncut and unpeeled.

Table 2. Description of the 8 sets of fruit and vegetable pictures.

Target food	Test picture 2 (fruit similar in colour)	Test picture 1 (vegetables dissimilar in colour)
Red tomato (T)	Red apple	(a) Orange squash (T) (b)White squash (A)
Green tomato (A)	Green apple	(a) Orange squash (T) (b)White squash (A)
Green zucchini (T)	Green banana	(a) Orange carrot (T) (b) Purple carrot (A)
Yellow zucchini (A)	Yellow banana	(a) Orange carrot (T) (b) Purple carrot (A)

Note: (T) = typically coloured vegetable; (A) = atypically coloured vegetable; (a) = different vegetable but typical colour; (b) = different vegetable and atypical colour.

our 8 triad sets. To this end, we converted each of the 8 triads into two pairs: the target and *dissimilar-in-color* test picture (Test picture 1), and the target and *similar-in-color* test picture (Test picture 2). In line with Gelman and Markman's study (1986; Exp. 1), for each pair, participants were asked to rate "how alike the two pictures look" on a scale of 1 (*not at all similar*) to 7 (*extremely similar*). An example of a very similar pair (thin slices of a yellow banana and crisps) was given. Adults' ratings of the pictures validated the experimental design pitting colour similarity against category membership. Overall, pictures designed to be more perceptually similar (e.g. red tomato and red apple; see Figure 1) were rated as significantly more similar ($M = 4.60$, $SD = 1.60$) than pictures belonging to the same taxonomic category (e.g. red tomato and orange squash; see Figure 1, $M = 2.67$, $SD = 1.47$) (Student's t test: $t = 11.07$, $ddl = 29$, $p < 0.0001$). Within each of these triads, we observed the same pattern, where the target picture and Test picture 2 (fruit) were judged to be more similar to each other than the target picture and Test picture 1 (other vegetable).

Procedure

Children were tested individually for approximately 10 min in a quiet room at their school and the procedure was approved by the local ethical committee. They sat at a table with an experimenter on their right side. During the task, the children were shown the 8 triad sets of pictures, one after the other. For each set, they were told a novel property about the target picture and asked to generalise this property to one of the two test pictures.[1] To ensure that the children did not draw on prior knowledge to make these decisions during the task, we used blank predicates, as in Fisher et al. (2015b), such as "contains zuline". Previous studies had indicated that blank predicates can be successfully used with children as young as 2 years (Fisher et al., 2011; Godwin, Matlen, & Fisher, 2013). However, blank predicates place relatively heavy information processing demands on young children, as they are required to focus their attention on several pictures at the same time and to learn new facts for each novel set of pictures (Gelman & Coley, 1990). Instead of using 8 different blank predicates, we therefore used just three ("contains zuline", "contains lima", and "contains kazole"), each predicate being repeated three or two times across the sets. To this end, we divided the 8 triad sets of pictures into three groups, each assigned one of the blank predicates. Each group contained three (or two) different vegetable targets, so that the children could not associate a predicate with one particular target. It is important to notice that from the behaviour of children during the task we did not see any apparent carry over effects from the repetition of the properties or the repetition of the Test picture 2 for a given target picture. Indeed children actually often justified their choice during the task, saying for instance that because the apple was also red it has the same property that the red tomato. Nevertheless they never made comments like "the red tomato can't contain zuline because the green tomato does" or "the apple contained zuline before so it does too now". The order of presentation of the three groups was randomised (but all trials telling a child that a food "contains zuline" were presented one after the other), as was the order of set presentation within the three groups.

Following the example of Gelman and Markman (1987), we created three conditions that varied in terms of whether the pictures were both labelled *and* shown (*word-and-picture* condition), shown without their labels (*picture-only* condition), or labelled but not shown (*word-only* condition). By varying what information is available to children, we can determine on what bases children draw inferences and whether it is influenced by food rejection disposition (namely food neophobia and pickiness). As condition was used as a between-participants variable, children were randomly assigned to one condition only (42 children per condition), with the constraint that conditions were roughly equivalent for, age and rejection level (mean age = 48.50 months, age range = 24–75, mean rejection score = 34.00, rejection range = 11–46 in the *word and picture* condition, mean age = 48.50 months, age range = 37–69 months, mean rejection score = 37,00, rejection range = 11–55 in the *word-only* condition, and mean age = 48.50 months, age range = 35–82 months, mean rejection score = 34.00, rejection range = 11–50 in the *picture-only* condition).

[1]It is worth noting that in Gelman and Markman's seminal study (1986), facts were given about individual test pictures, meaning that several different facts were provided for each set. As the children in our study were younger than in hers, we used the reverse procedure, as in Gelman and Coley (1990) and Gelman and Markman (1987), and administered a forced-choice task, as the yes/no paradigm used in Gelman and Markman (1987) is not always appropriate for young children (Thibaut et al., 2016).

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Word-and-picture condition: In this condition, for each triad, the experimenter began by pointing to the three pictures, labelling each of them in turn (starting with the target picture, then the two test pictures in a balanced order). For example, the experimenter pointed to the target picture and said "Look, it's a tomato" and then pointed to the test pictures and said "Look, it's a squash and an apple". She then provided a fact about the target picture, while pointing to it, such as "This tomato contains zuline". Finally, she asked children about the two test pictures (e.g. "Do you think this squash [pointing to the squash] or this apple [pointing the apple] also contains zuline?"). Children could only choose one of the two test pictures. It should be noted that although we were testing fruit and vegetable category membership, we decided to use the labels of the basic-level categories (e.g. *tomato* or *apple* instead of *vegetable* or *fruit*). We wanted these labels to activate category membership (and children were familiar with all these labels) and young children are said to believe that count labels denote categories (Fisher et al., 2015a). But we did not want to emphasise the vegetable items' overall similarity (identical labels are sometimes thought to enhance similarity between items; see Sloutsky & Fisher, 2004). This condition provided children with category information and perceptual information.

Picture-only condition: In this condition, the difference with the word-and-picture condition was that the foods were never labelled (e.g. the experimenter said "Look at *this*. *It* contains zuline"). This condition was used to draw children's attention to perceptual cues and did not facilitate category recognition. For instance we did not expect children to categorise as a tomato the green tomato because it was really an atypical colour for this vegetable.

Word-only condition: In this condition, contrary to the word-and-picture condition, the foods were never shown to the children (e.g. the experimenter said "I see a picture of a tomato"). This condition was used to draw children's attention to information conveyed by labels, as it was the only available source of information. Category recognition was therefore facilitated. This latter condition placed heavier memory demands on children. However, as demonstrated in recent studies, preschoolers can remember the identity of hidden objects with a high degree of accuracy (Fisher et al., 2011; Godwin et al., 2013).

Scoring

The experimenter recorded participants' responses to the task, assigning a score of 1 to category-consistent responses (i.e. if the participant generalised the property to the other vegetable) and a score of 0 to perceptual-consistent responses (i.e. if the participant generalised the property to the fruit). The scores were then summed across all the sets to obtain the number of category-consistent responses for each participant. This number was divided by the total number of set (8) to obtain the child's induction score (possibly ranging from 0 to 1).

It should be noted that despite the fact that taxonomic categories are not always the most pertinent categories to draw inferences (see Coley, Shafto, Stepanova, & Baraff, 2005, for the use of thematic categories and causal relations in induction), the emphasis on taxonomic relatedness as "good answer" in the present research is based on the type of properties used. Indeed, in this study, the properties to be generalised were *biological* properties, and children and adults used taxonomic categories to generalise these kinds of properties (Coley et al., 2005; Nguyen & Murphy, 2003; Thibaut et al., 2016). Nevertheless, one could argue that in the food domain colour is as predictive as taxonomic category membership (for instance it is been showed that colour is used to predict caloric content of a food; Foroni et al., 2016). However adults' participants in the present study chose the category-consistent response to generalise knowledge 88.8% of the time (significantly above chance level, $t = 11.36$, $ddl = 21$, $p < 0.0001$) strengthening the choice of scoring category-consistent responses as "good answers".

Results

Linear model repeated measures analysis was performed with scores on the category-based induction task (possibly ranging from 0 to 1) as dependent variable, triad's complexity (*typically coloured target and test picture 1; atypically coloured target and test picture 1; typically coloured target and atypically coloured test picture 1; atypically coloured target and typically coloured 1est picture 1*) as within-participants factors and condition (*word-and-picture*; *picture-only*; *word-only*), age, CFRS scores and exposition scores as between-participants factors. As preliminary analyses revealed no effect of the order of presentation of the triads ($p > 0.15$), we collapsed the data across this variable for the analyses reported below.

This analysis revealed a significant effect of condition, $F(2, 114) = 4.60$, $p = 0.012$, $\eta_p^2 = 0.046$. Bonferroni corrected post hoc comparisons indicated that the *word-only* condition differed significantly from the *word-and-picture* condition ($p = 0.018$). Children performed significantly better in the *word-only* condition ($M = 0.58$, $SD = 0.30$)-and were almost above chance level ($t = 1.75$, $ddl = 41$, $p = 0.08$)—than children in the *word-and-picture* condition ($M = 0.40$, $SD = 0.25$) who were below chance level ($t = -2.44$, $ddl = 41$, $p = 0.019$). The post hoc analysis also revealed that the *picture-only* condition did not significantly differ from either the *word-and-picture* condition or the *word-only* condition.

This analysis also revealed a significant effect of CFRS scores, $F(1,114) = 6.33$, $p = 0.01$, $\eta_p^2 = 0.033$. As predicted by the hypothesis 1a of the study, food rejection scores were negatively correlated with performances (as attested by Spearman's correlation coefficient, $r = -0.19$, $p = 0.029$, see the black line on Figure 2). The more the neophobic and picky the children were the more they seemed to focus on perceptual cues to draw induction.

No significant effects of triad complexity (contrary to hypothesis 2a), age or exposure scores were found (all $ps > 0.15$). Contrary to hypothesis 1b and 2b, we also did not find any interaction effects between triad complexity and other main factors or interaction effects between condition and other main factors (all $ps > 0.35$).

To further assess the potential influence of food rejection disposition on category-based induction performances, we looked at the correlation between generalisation scores and food rejection scores in the two significantly different experimental conditions (*Word-and-picture* and *Word-only*). The correlation was significant in the *Word-and-picture* condition (Spearman's correlation coefficient, $r1 = -0.35$, $p = 0.019$, see the blue dashed line on Figure 2), but not in the *Word-only* condition (Spearman's correlation coefficient, $r2 = -0.16$, $p = 0.31$, see the red dashed line on Figure 2). To compare these two correlation coefficients we used a Fisher transformation to obtain $r'1 = -0.36$ and $r'2 = -0.16$ with the following formula Cohen and Cohen (1983):

$$r' = \frac{1}{2}\ln\left|\frac{1+r}{1-r}\right|$$

We then measured a *Z*-score for the differences between the correlation coefficients:

$$Z = \frac{r'_1 - r'_2}{E} \quad \text{with}$$

$$E^2 = \frac{1}{n1-3} + \frac{1}{n2-3} = -0.90$$

indicating that the two correlation coefficients did not significantly differ ($p > 0.1$).

Discussion

The present study had two aims. First, we sought to investigate the role of individual differences in food rejection behaviours in children's induction within the domain of food categories. Second, we wanted to shed light on the mechanisms behind the existing consensus on the central role of colour in the food domain.

Development of food category-based induction and sensitivity to individual differences

Results concerning the sensitivity of category-based induction performances to food rejection dispositions supported our hypothesis 1a. First statistical analyses indicated that overall children with high food rejection dispositions demonstrated poorer induction performances than children with lower food rejection dispositions. This suggests that the children's level of food rejection partly predicted their performance on the fruit and vegetables induction task: neophobic and picky children tended to generalise knowledge based on perceptual cues (in this case colour cues) rather than category membership. Furthermore, statistical analyses within the two significantly different experimental conditions (*word-only and word-and-picture*) revealed that contrary to the hypothesis 1b, the correlation coefficient between children CFRS scores and category-based induction scores in the *word–and-picture* condition, did not differ significantly from the correlation coefficient in the *word-only* condition. This later result suggests that differences between neophobic children and their counterparts could arise from (i) the fact that, compared with children with few rejection dispositions, highly neophobic children are more likely to rely on colour similarity to draw inferences when this information is available. This is in line with a study using an eye tracking procedure (Maratos & Staples, 2015), where the authors found

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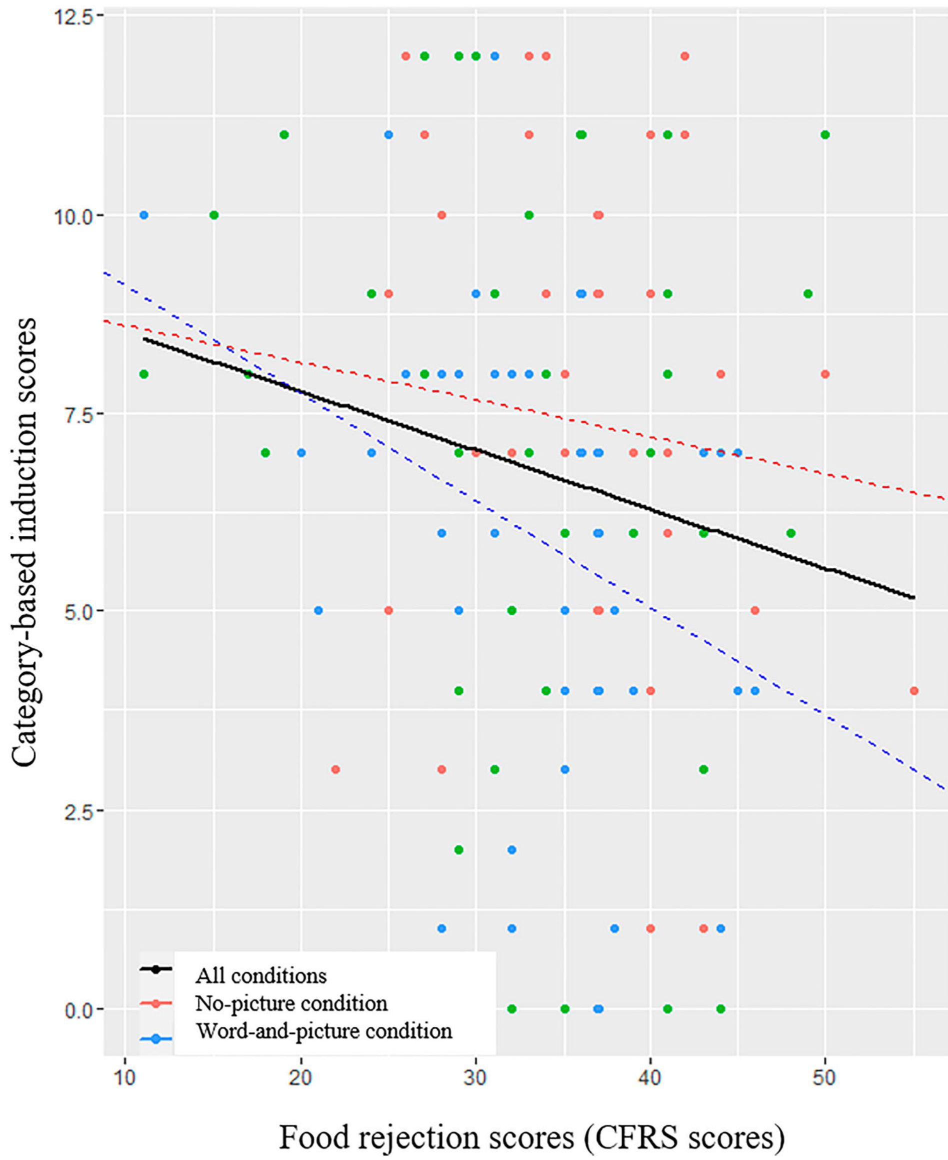

Figure 2. Children's scores on the property generalisation task as a function of their food rejection scores.
Note: Only the word-and-picture and the word-only conditions are depicted in dashed lines as they significantly differ.

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that neophobic children demonstrated an attentional bias toward the visual aspect of food stimuli. Because we found no differences in the two correlation coefficients, differences between neophobic-picky children and their counterparts could also arise from (ii) differences in their semantic development. Indeed in a recent study using a paradigm highly similar to our *word-only* condition, Fisher et al. (2015b) showed that category-based induction abilities were strongly and positively correlated with semantic development. This is less likely however because in a follow up study we conducted with the older children of our sample ($n = 63$; age range = 48–82 months) we did not find any correlation between CFRS scores and performances to a semantic space task (similar to Fisher and colleagues' task; 2015b). Highly neophobic and non-neophobic children performed equally to a semantic task where they were asked to help us organise our groceries of fruits and vegetables by placing food items similar in kind (e.g. two vegetables) close together in the shopping trolley and food items dissimilar in kind (e.g. a fruit and a vegetable) far away from each other in the shopping trolley. Unpainted wooden blocks were used as game pieces to put in the trolley to encourage children to use their knowledge about kinds rather than rely on perceptual similarity.

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In the light of these original results, we hypothesised that we could be facing a vicious circle. Food rejection may be seen as the result of an immature food categorisation system (Brown, 2010; Dovey et al., 2008; Lafraire et al., 2016; Rioux et al., 2016). Indeed, food acceptance depends on recognition because children are more comfortable eating food items for whose they can anticipate the consequences of ingestion (Pliner & Hobden, 1992). Food rejections exhibited by certain children may in turn discourage caregivers to present fruit and vegetables to their children because of reluctance to waste food (Carruth et al., 2004). This lack of exposure to fruit and vegetables will lead to fewer learning opportunities which, in turn, impacts negatively on food categorisation and inductive reasoning (as the present study revealed). A promising way to break this circle would be to investigate the early food categorisation system to design interventions aiming at enriching it. It could be more effortless for caregivers to provide children with games designed to enhance their conceptual knowledge, especially if it occurs outside mealtimes that carry the stress associated with ensuring the child is consuming a healthy diet (Dazeley & Houston-Price, 2015) than to repeatedly present vegetables to them. Nevertheless future research exploring with longitudinal designs the relationship between cognitive development and food rejection dispositions is needed to better grasp causal influences in the original relationship revealed in the present study.

Importance of color in food induction

Results concerning the effect of colour typicality did not support our hypothesis 2a and 2b. Food items with atypical colours were no more prone to induction errors than food items with typical colours. Additionally, results did not reveal any interaction effect between colour typicality and children food rejection dispositions. This absence of a significant effect of colour typicality was not in line with previous studies focusing on the role of either colour typicality in food categorisation (Rioux et al., 2016) or typicality in inductive inferences (Dunsmoor & Murphy, 2014). Rioux and colleagues found that when children were presented with fruit and vegetables that differed in shape, colour or colour typicality, colour typicality was the most salient variable, predicting whether or not food items were correctly categorised. Additionally, Dunsmoor and Murphy (2014) found that for adult participants, novel properties involving typical exemplars of a category were applied to other members of that category, whereas a premise about atypical exemplars was more narrowly generalised to other category members. An important difference between Dunsmoor and Murphy's study (2014) and the present study is that we used fairly common and typical kinds of fruit and vegetables (apples, bananas, carrots, tomatoes, squashes and zucchini), and manipulated *colour* typicality instead of *kind* typicality as Dunsmoor and Murphy did. It is therefore possible that even atypically coloured vegetables were recognised by children, and they perceived no differences in typicality in the presented triad sets. In fact we did not find any significant differences between the *Word-and-picture* condition and the *Picture-only* condition suggesting that children were able to recognise the vegetables (either typically or atypically coloured) even without hearing the labels. The absence of any significant effect of colour typicality could also be explained by our rather small triad sample (8 triads in total). A much broader sample may have been needed to detect a significant typicality effect (in Rioux et al.'s study, 2016, a typicality effect was found with a sample of 36 pictures). However, children as young as 2 years have a short attention span and the present induction task therefore had to be brief in order to maintain their attention throughout the test. More research on the importance of colour typicality within the food domain is therefore required with older children (e.g. 4- to 6-year-olds), who can be asked to perform tasks with more stimuli.

Conclusion and perspective

Our results provided the first piece of evidence in favour of a negative correlation between food rejection and food category-based induction performances in young children and reinforced recent findings demonstrating the same pattern of results, namely that young children perform the same as neophobic and picky children on a fruit and vegetable discrimination task (Rioux et al., 2016).

We nevertheless acknowledge that the present study had several limitations. First, we used photographs of real food items. Colour similarity was therefore not total (e.g. the red of the tomato and the red of the apple were not exactly the same), and may have reduced children's use of colour

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similarity to draw inductive inferences. However, children are thought to be faster at distinguishing between two colours that belong to different categories (e.g. yellow and red) than two colours that belong to the same category (e.g. two different reds), even when the distance in hue is objectively the same (for a review of colour perception, see Timeo, Farroni, & Maass, 2016). Nevertheless, it would be worth confirming the patterns of results of the present study by controlling for colour similarity.

Second, as we were interested in colour similarity, we selected fruit and vegetables with similar overall shapes, to control for that possible effect. However, the children may have found that shape similarity was greater for the two vegetables than for the vegetable and the fruit, thus reducing the conflict between perceptual information and categorical knowledge. It would be worth confirming these patterns by controlling better for shape similarity.

Finally, colour typicality had to be assessed by an external sample of adults, rather than by the children themselves, as it is rather difficult to directly ask children as young as 2 years whether they think that a colour is typical of a given fruit or vegetable, as t*ypicality* is an abstract concept they probably do not understand. That said, when children are simply asked to categorise items, they prove to be more accurate with typical items than with atypical ones (Murphy, 2002). In future studies, it would therefore be worthwhile assessing children's performances on a categorisation task with this same set of coloured stimuli, in order to gain an estimation of their typicality for children.

Despite these limitations, we believe that the present experiment opens up promising new research avenues, and sheds light on the relationships between cognitive mechanisms and different kinds of food rejections (neophobia and pickiness). For instance, it will be of interest to investigate children induction performances with other food categories that are less prone to rejections (such as starchy foods) or with non-food items and investigate whether the negative correlations between induction performances and food rejections scores continue to exist. A second promising line of research would be to explore the effect of training in food category-based induction tasks on food rejection disposition during childhood. The highly neophobic and picky children who relied heavily on colour similarity to draw inferences in the present experiment should benefit from such training, as they would learn that colour similarity should be disregarded in favour of labels that facilitate recognition of category membership, when making predictions about food items. They might then reject fewer food items because they are not perceptually close enough to the food prototype.

Such a strategy grounded in conceptually-based approach is in line with the recent research by Gripshover and Markman (2013). In their study, they compared the usual educational programmes about nutrition (where simple facts about nutrition are given to children) with a nutritional education programme that adopted a *knowledge-based approach*, giving children a rich conceptual framework so that they would understand the need to eat a variety of healthy foods. These authors found that children who attended the latter programme ate more vegetables at snack time (similar findings were found by Nguyen, McCullough, and Noble (2011), using a comparable theory-based education programme).

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PART D. DESIGNING A VISUAL EXPOSURE INTERVENTION TO OVERCOME FOOD REJECTIONS

Chapter 8. Visual exposure and categorization performance positively influence 3- to 6-year-old children's willingness to taste unfamiliar vegetables

This chapter focuses on the development of an intervention, based on visual exposure and exploiting the empirical evidence on the relationship between cognitive development and food rejections, to positively influence children food rejection behaviors.

The visual exposure intervention was developed in a school setting (and more precisely in a school cafeteria setting), and not in a home setting, for several reasons. First, school seems to be an effective environment for teaching children about nutrition and healthy eating (Perez-Rodrigo & Aranceta, 2001). Second, the school provides an educative learning environment in which children are used to be exposed to educative interventions (Battjes-Fries, 2016). Finally, using a school setting enables to expose in the same way the different children to food pictures. Indeed, with home interventions, caregivers may not dedicate the same amount of time to expose their children to food pictures (Houston-Price, Burton, Hickinson, Inett, Moore, Salmon, & Shiba, 2009).

The intervention phase was settled in school cafeterias, therefore children were exposed to food pictures collectively. Before and after the intervention phase, children were asked to participate to different tests to assess potential changes due to the intervention. To avoid any peer modeling cofounding effect, baseline and post-intervention tests were conducted individually (see Hendy, 2002, for a study on peer modeling effect on food acceptance).

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Visual exposure and categorization performance positively influence 3- to 6-year-old children's willingness to taste unfamiliar vegetables

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A B S T R A C T

The present research focuses on the effectiveness of visual exposure to vegetables in reducing food neophobia and pickiness among young children. We tested the hypotheses that (1) simple visual exposure to vegetables leads to an increase in the consumption of this food category, (2) diverse visual exposure to vegetables (i.e., vegetables varying in color are shown to children) leads to a greater increase in the consumption of this food category than classical exposure paradigms (i.e. the same mode of presentation of a given food across exposure sessions) and (3) visual exposure to vegetables leads to an increase in the consumption of this food category through a mediating effect of an increase in ease of categorization. We recruited 70 children aged 3–6 years who performed a 4-week study consisting of three phases: a 2-week visual exposure phase where place mats with pictures of vegetables were set on tables in school cafeterias, and pre and post intervention phases where willingness to try vegetables as well as cognitive performances were assessed for each child. Results indicated that visual exposure led to an increased consumption of exposed and non-exposed vegetables after the intervention period. Nevertheless, the exposure intervention where vegetables varying in color were shown to children was no more effective. Finally, results showed that an ease of categorization led to a larger impact after the exposure manipulation. The findings suggest that vegetable pictures might help parents to deal with some of the difficulties associated with the introduction of novel vegetables and furthermore that focusing on conceptual development could be an efficient way to tackle food neophobia and pickiness.
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1. Introduction

Over the past years concern has arisen over the lack of children's dietary diversity, which is necessary for healthy development (Falciglia, Couch, Gribble, Pabst, & Frank, 2000). This lack of variety is directly associated with poor intake of fresh products such as fruits and vegetables, far below the recommended intake of five portions a day (Coulthard & Blissett, 2009). Arguably, *food neophobia* (defined as the reluctance to eat new foods; Pliner & Hobden, 1992) and *food pickiness* (defined as the rejection of new foods and certain familiar foods; Taylor, Wernimont, Northstone, & Emmett, 2015) are two strong barriers to children's higher consumption of fruits and vegetables (Birch & Fisher, 1998; Dovey, Staples, Gibson, & Halford, 2008; Galloway, Lee, & Birch, 2003; Lafraire, Rioux, Giboreau, & Picard, 2016). Because the impact of these two kind of food rejections extends well beyond childhood, as dietary habits acquired during this period partly determine dietary patterns in adulthood (Nicklaus, Boggio, Chabanet, & Issanchou, 2005), it is essential to design effective interventions that aim to overcome children's food neophobia and pickiness.

1.1. The impact of mere exposure on children's food acceptance: a role for visual exposure

According to the “mere exposure” theory, the exposure to one instance of a given stimulus is sufficient to trigger a more positive attitude toward a subsequent instance of that particular stimulus (Zajonc, 1968). A considerable body of research has therefore investigated whether repeated taste exposure to fruits and vegetables might be employed to enhance children's acceptance and

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reduce rejections (for a review on food exposure see Cooke, 2007; Keller, 2014). There is considerable support for the success of such repeated taste exposure in controlled experimental settings (Birch & Marlin, 1982; Birch, Mcphee, Shoba, Pirok, & Steinberg, 1987) as well as in more ecological settings like home or school environments (Mustonen & Tuorila, 2010; Park & Cho, 2015). However these intervention programs often lead to a significant increase for children's fruit intake, but only minor changes for vegetable intake (Appleton et al., 2016; Evans, Christian, Cleghorn, Greenwood, & Cade, 2012). Additionally these strategies may have limited efficacy in reducing neophobia or pickiness since several studies revealed that 10 to 15 taste exposures to a new food item may be needed for its successful acceptance in preschool-aged children (Birch et al., 1987; Wardle, Carnell, & Cooke, 2005). This is a number greater than most parents are willing or able to provide (Carruth, Ziegler, Gordon, & Barr, 2004).

Because a neophobic reaction results in foods being rejected on mere sight (Cashdan, 1998; Dovey et al., 2008), it is reasonable to assume that *visual* exposure could actually be more effective to reduce food rejections than *taste* exposure. In addition, it could be more effortless for caregivers to provide visual exposure to food (e.g. through picture books), especially if it occurs outside mealtimes. There is in fact an encouraging body of evidence to support research into the impact of visual exposure on children's food rejections (Heath, Houston-Price, & Kennedy, 2011, 2014; De Droog, Buijzen, & Valkenburg, 2014; Houston-Price, Butler, & Shiba, 2009; Osborne & Forestell, 2012). For example, providing 2- to 6-year-old children with picture books about leeks and carrots, Heath et al. (2011) and De Droog et al. (2014) showed that toddlers consumed more of the vegetable they had seen in their picture book, compared to a matched control vegetable.

1.2. The impact of mere exposure on children's food acceptance: a role for diverse visual exposure

In the large majority of studies that investigate the effect of mere food exposure, children were exposed to the same mode of presentation of a given food across exposure sessions (Caton et al., 2013; Olsen, Ritz, Kraaij, & Moller, 2012). For instance, in Caton and colleagues' study (2013), infants received the same preparation of artichoke puree for ten days, prepared with commercialized baby food. However, a recent study conducted by Houston-Price, Burton, et al. (2009) revealed that offering children different modes of presentation of a food could lead to greater interest in this food. They exposed toddlers for two weeks, either to picture books containing five *identical* pictures of a given fruit (e.g. apple), or to picture books containing five *different* pictures of the same fruit (e.g. an apple on a tree, an apple cut up on a plate etc.). They found that toddlers' looking interest in the exposed fruit was greater in the latter condition. They hypothesized that toddlers' more positive attitude toward the fruit after the "diverse" exposure intervention was driven by experiences that had allowed them to furnish an elaborate representation in mind of the exposed food.

This kind of "diverse" exposure could be greatly beneficial for children with high food neophobia and pickiness. In a recent study Rioux, Lafraire, and Picard (under revision) showed that 2- to 6-year-old neophobic and picky children tended to generalize knowledge to novel foods based on color similarity instead of category membership (see Murphy, 2002, pp. 371–375 for a summary of the development of induction in childhood). For instance when taught a new fact about a red tomato, they tended to generalize it to a red apple rather than to a green tomato. Food rejections exhibited by certain children may discourage caregivers from presenting fruit and vegetables to their children. This would lead to fewer learning opportunities and to poor representation of fruit and vegetable categories tied to perceptual properties, such as color, explaining poor category-based induction abilities (see Lavin & Hall, 2001 and Macario, 1991, for the importance of color over shape in the food domain). In this instance "diverse" exposure that allows children to furnish an elaborate mental representation of the food, as in Houston-Price, Burton and colleagues' study (2009), should greatly benefit neophobic and picky children. These children, who relied heavily on color similarity for induction in Rioux and colleagues' experiment, should benefit from exposure intervention and learning opportunities that expose them to diverse colors for given food items. They could learn that color similarity should be disregarded, in favor of labels, when making predictions and consumption choices about food items. It is therefore worth exploring further the potential for visual exposure, with various presentations of the same food across exposure sessions.

1.3. The mechanisms behind mere exposure

Surprisingly, while a large body of research has investigated the potential effect of exposure, the accepted mechanistic explanation remains elusive. One of the mechanisms by which exposure is assumed to engender a positive attitude toward a stimulus is thought to be "learned safety" (Kalat & Rozin, 1973; Zajonc, 2001). Exposure removes our natural fear of new stimuli through a process of conditioning. Indeed repeated ingestion of an unfamiliar food without negative consequences will lead to increased acceptance of this food (Cooke, 2007). Nevertheless, the recent evidence that mere visual exposure could also enhance the acceptance of unfamiliar food items (De Droog et al., 2014; Osborne & Forestell, 2012) casts doubt on whether the "learned safety" hypothesis entirely explains the positive effect of exposure. Additionally, since rejections usually occur at the mere sight of the food (Dovey et al., 2008), there are valid grounds for assuming that food appearances might play a more central role than the absence of post-ingestion consequences, in a child's decision to consume a novel food item (Heath et al., 2011).

An alternative explanation, which embodies a cognitive approach to the mere exposure effect, was offered by Bornstein and D'Agostino (1994). By increasing the amount of experience an individual has with any stimulus, repeated exposure increases the ease and speed with which the stimulus is categorized, leading to a positive attitude toward the stimulus (Bornstein & D'Agostino, 1994; Seamon, Williams, Crowley, Langer, Orne, & Wishengrad, 1995). Categorization is a fundamental cognitive process that allows us to organize objects into groups (Vauclair, 2004). When a food item is first presented to a child it is organized into categories relating to its characteristics (Murphy, 2002; Vauclair, 2004; see also Lafraire et al., 2016). Knowledge gained through this first encounter allows for easier and faster categorization, when subsequently presented with the same or a similar food item (Aldridge, Dovey, & Halford, 2009).

According to this cognitive approach, this ease in categorization of a given food item should lead to a reduction of food neophobia and pickiness. A recent study supports this hypothesis. Rioux, Picard, and Lafraire (2016) showed that categorization performance predicted food neophobia and pickiness. The authors asked children to sort pictures of fruits and vegetables into two different boxes according to their categories, and found that children with poor categorization performance were likely to be highly neophobic and picky. Hence, they proposed that food acceptance depends upon categorization (Rioux et al., 2016; see also; Brown, 2010; Dovey et al., 2008).

Nevertheless it is important to note that within this cognitive approach it remains to be seen if positive effects are restricted to the exposed stimulus (e.g. a carrot) or are generalizable to other instances of the category of the exposed stimulus (e.g. other vegetables like tomato). Evidence for this in the literature is not clear: in one study, it was observed that changes were restricted to the target food (Mennella, Nicklaus, Jagolino, & Yourshaw, 2008) while transfer effects were observed in another studies (Birch, Gunder, Grimm-Thomas, & Laing, 1998; Tuorila, Meiselman, Bell, Cardello, & Johnson, 1994). For instance, Mennella and colleagues (2008) found that repeated exposure to pureed potatoes did not enhance acceptance of pureed carrots. Conversely, Birch et al. (1998) found that repeated exposure to bananas enhanced intake of pears.

It was originally proposed by Bornstein and D'Agostino (1994) that exposure to a stimulus facilitates categorization only for that given stimulus. It is also plausible that positive effects are due to an enrichment of the content of the category at hand and then facilitate subsequent categorization for other instances of the same category (Lafraire et al., 2016). Indeed, the richer the experienced content of the category, the higher the probability of an acceptable similarity between a non-exposed stimulus and representations in mind (Murphy, 2002).

1.4. The present study

The goal of the present study was to explore further the potential for visual exposure and to investigate the mechanisms responsible for its impact. We tested the effectiveness of an intervention among children who were exposed to different pictures of vegetables, compared with a control group of children, who were not exposed these pictures. Based on the theoretical framework described above, we had three main hypotheses:

(1) Simple visual exposure to vegetables leads to an increase in the consumption of this food category.
(2) Diverse visual exposure to vegetables (i.e., vegetables varying in color are shown to children) leads to a greater increase in the consumption of this food category than classical exposure paradigms (i.e. the same mode of presentation of a given food across exposure sessions).
(3) Visual exposure to vegetables leads to an increase in the consumption of this food category through a mediating effect of an increase in ease of categorization.

2. Materials and method

2.1. Participants

The participants were 70 children, aged 34–68 months (40 girls and 30 boys, mean age = 51.43 months, *SD* = 8.62). They were all-day pupils eating lunch in the cafeteria at three preschools in Lyon (France) and came from middle-class communities (as defined by the city of Lyon, principally based on the number of pupils with scholarships and average parental incomes). Prior to the study, the parents of each child filled out the Child Food Rejection Scale (CFRS; Rioux, Lafraire, & Picard, 2017) to assess his or her food neophobia and pickiness. CFRS scores could range from 11 to 55 with high scores indicating high food neophobia and pickiness. Parents were also asked to indicate their child's liking for the 6 types of vegetables in the study (beetroots, bell peppers, cauliflowers, carrots, tomatoes, and zucchini) on a 7-point Likert scale (from *hate* to *love*, with a high score indicating high liking). Finally, parents were asked to indicate at which frequency each colored vegetable (green tomatoes, red tomatoes, red bell peppers, etc.) was consumed at home using a 5-point Likert scale (from *never* to *more than once a week*, with a high score indicating high frequency of consumption).

2.2. Study design

This 4-week study consisted of three phases: a *visual exposure phase* where place mats were set on tables in the cafeteria of the three schools participating in the study, and *pre and post intervention phases* where Willingness to Try Vegetables (WTV) as well as cognitive performances were assessed for each child. An overview of the study design is shown Fig. 1. The design was approved by a local ethical committee.

In this 2-week intervention phase, the three schools participating in the study were randomly assigned to one of the three experimental conditions: *simple exposure* condition (n_2 = 24; 13 girls and 11 boys, mean age = 52.21 months, *SD* = 9.45), *diverse exposure* condition (n_3 = 26; 17 girls and 9 boys, mean age = 54.08 months, *SD* = 8.08) and *control* condition (n_1 = 20; 10 girls and 10 boys, mean age = 46.56 months, *SD* = 6.25). The choice of using separate schools for the different conditions resulted from the need to avoid allowing children from different conditions to exchange information about the intervention. However, the three schools were located in the same neighborhood to avoid any socio-demographic confounding effects.

In each of the three schools, place mats were set every day on cafeteria tables, for two consecutive weeks, therefore children were exposed to these mats eight times (as cafeterias are closed on Wednesdays). Each place mat was printed on a laminated card measuring 21 × 29.7 cm and contained five color pictures. The five pictures printed on the mats depended on the intervention condition assignment:

(1) *Simple exposure condition (SE).* In this school, the *same* place mat with five unfamiliar vegetables was presented to children eight times. The main difference between the present study and previous studies of exposure's effect on willingness to try unfamiliar vegetables was the source of unfamiliarity. Indeed in our study, the vegetables themselves were commonly served in the school canteen but the unfamiliarity came from the atypical color of the vegetables: green tomato, purple cauliflower, white beetroot, yellow bell pepper, and purple carrot (see Fig. 2a).
(2) *Diverse exposure condition (DE).* In this school, place mats presented the same kinds of vegetables as in the previous condition. However, contrary to the *simple exposure* condition where one vegetable was always presented in the same color, in this condition each of the five vegetables was presented in four different atypical and unfamiliar colors (see Fig. 2b). Therefore in this condition four different mats were presented to children, for two successive days each.
(3) *Control condition (C).* In this school, the same place mats with pictures of five stones were presented to children (see Fig. 2c). The five stones were selected to match for unfamiliarity and color diversity with the vegetables printed on the mat of the *simple exposure* condition.

2.3. Baseline and post-test

Both at baseline (T0) and post-test (T1) phases, children were seen individually for approximately 15 min in a quiet room at their school on a Friday afternoon. They sat at a table with an experimenter by their side and performed in a constant order a forced-sorting task and a category-based induction task to assess their cognitive performances and then a Willingness to Try Vegetables task (WTV).

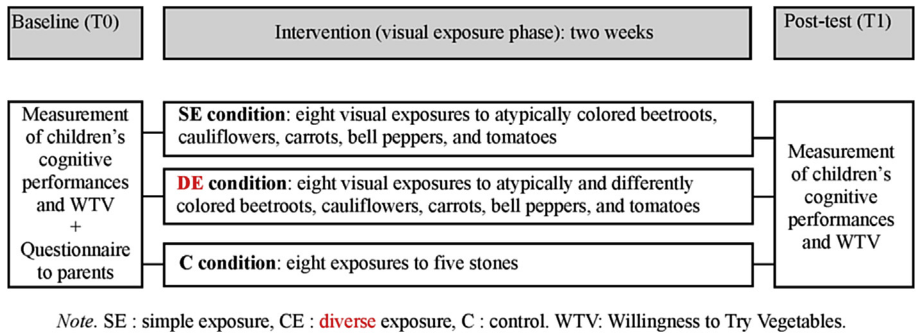


Fig. 1. Overview of the experimental design.

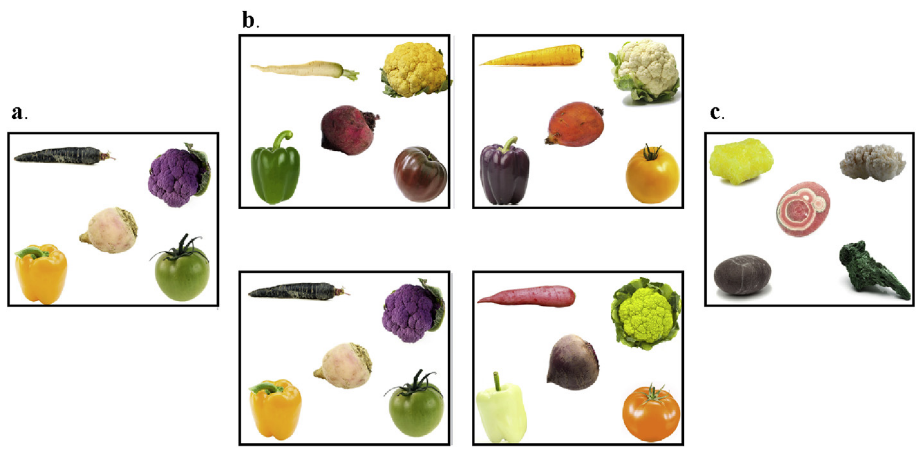


Fig. 2. Place mats of simple (a) and diverse (b) exposure conditions and control (c) condition.

2.4. Categorization task

This task aimed to assess children's categorization performance. Following the same protocol as in Rioux et al. (2016), children were shown successively two blocks of twelve pictures each of fruit and vegetables printed separately on laminated cards measuring 10 × 15 cm. Some vegetables had typical colors (e.g., a purple beetroot), while some had atypical colors (e.g., a yellow beetroot; see Table 1 for the description of the two blocks). For each block, the children were asked to find the vegetable pictures and place them in a box, and then place the other pictures in the other box (the other pictures were the fruit pictures but we did not tell the children they were fruits). The order in which the blocks were provided was counterbalanced across participants. The experimenter then assigned four scores to each participant:

(i) a hit score (i.e. number of cards placed in the vegetable box when the picture was indeed a vegetable).
(ii) A false alarm score (i.e., number of cards placed in the vegetable box when the picture was a fruit).
(iii) A miss score (i.e. number of cards placed in the fruit box when the picture was a vegetable).
(iv) A correct rejection score (i.e. number of cards placed in the fruit box when the picture was indeed a fruit).

Based on these scores we calculated an index of categorization A (ranging from −2.75 to 2.75, with a high score indicating good categorization performance) derived from signal detection theory (Macmillan & Creelman, 2005), but adapted to the needs of experiments with low numbers of stimuli (successfully used in Morin-Audebrand, Mojet, Chabanet, Issanchou, Møller, Köster, &

Table 1
Description of the two blocks of fruit and vegetable pictures.

Block 1			Block 2		
Bell pepper (quarter)	Zucchini (slice)	Pear (cube)	Eggplant (cube)	Tomato (quarter)	Citrus fruit (slice)
Green (T)	Green (T)	Yellow	Dark purple (T)	Red (T)	Green
Red (T)	Dark green (T)	Green	Light purple (T)	Dark red (A)	Yellow
Yellow (A)	Light green (A)	Brown	White(A)	Yellow(A)	Pink
Orange (A)	Yellow (A)	Red	Green(A)	Green(A)	Orange

Note. (T) = typical color. (A) = atypical color assessed in Rioux et al. (2016). The colors reported here are the skin colors of each fruit or vegetable. In each block, there was the same number of food items cut in quarters, slices and cubes.

Table 2
Description of the eight sets of fruit and vegetable pictures.

Target food (vegetable)	Test picture 1 (fruit similar in color)	Test picture 2 (vegetable dissimilar in color)
Red tomato (T)	Red apple	(1) Yellow bell pepper (T) (2) Purple bell pepper (A)
Green tomato (A)	Green apple	(3) Yellow bell pepper (T) (4) Purple bell pepper (A)
Green zucchini (T)	Green banana	(5) purple eggplant (T) (6) white eggplant (A)
Yellow zucchini (A)	Yellow banana	(7) purple eggplant (T) (8) white eggplant (A)

Note. (T) = typically colored vegetable; (A) = atypically colored vegetable.

Sulmont-Rossé, 2012).

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

with N_H, N_M, N_{FA} and N_{CR} respectively corresponding to the numbers of hits, misses, false alarms and correct rejections. With regard to performance, a categorization index higher than zero means that participants answered more often "vegetables" for the vegetable pictures than for the fruit pictures.

2.4.1. Category-based induction task

This task aimed to assess children's use of taxonomic categories to generalize knowledge. Following the same protocol as in Rioux and collaborators (under revision) children were successively shown eight sets of three color pictures: one vegetable target picture and two test pictures (each triad set was printed on a laminated card measuring 21 × 29.7 cm, see Table 2 for a description of the eight sets). For each set, children were told an invented property about the target vegetable picture (such as "contains zuline", to ensure they did not use prior knowledge to draw induction; Fisher et al., 2015). Then they were asked to generalize this property to one of the two test pictures: one fruit similar in color to the target vegetable (*Test picture 1*) or one other vegetable dissimilar in color to the target vegetable (*Test picture 2*).[1] To heighten the conflict between category membership and color similarity, the labels of the pictures (which can facilitate category recognition) were not provided (the experimenter said "Look at *this*. *It* contains zuline"). The experimenter recorded participants' responses to the task, assigning a score of 1 to category-consistent responses (i.e., if the participant generalized the property to the other vegetable) and a score of 0 to perceptual-consistent responses (i.e., if the participant generalized the property to the similar-in-color fruit). The scores were then summed across all the sets to obtain the number of category-consistent responses for each participant. This number was divided by the total number of test sets (8) to obtain the child's category-based induction score (ranging from 0 to 1, with a high score indicating good category-based induction performances).

2.4.2. Willingness to try vegetables task (WTV)

This task aimed to assess children's willingness to try unfamiliar vegetables. Following the principle of the seminal food choice task by Pliner and Hobden (1992) eight pieces of vegetables arranged in four pairs were presented to children. Within each pair the same vegetable was presented in two colors: one typical (e.g. orange carrot) and one atypical (e.g. purple carrot). The four pairs of vegetables were as follows: (1) orange and purple carrot, (2) red and green tomato, (3) red and orange bell pepper, and (4) green and yellow zucchini. The typically colored vegetables were *a priori* familiar food items while the atypically colored vegetables were *a priori* unfamiliar vegetables and data collection from the parents supported this assumption: the four atypically colored vegetables were eaten less than once a month on average (all means < 2.3) while the four typically colored vegetables were eaten almost once a week on average (all means > 3). The frequency of consumption of each atypically colored vegetables was significantly lower than its typically colored match (all $ps > 10^{-7}$).

It is important to note that while at baseline (T0) the four atypically colored vegetables had the same status (i.e. *unfamiliar*), after the intervention (T1) they had different status because:

(i) Purple carrot and green tomato were present on the place mats in both *exposure* conditions (see Fig. 1a and b), and are hereinafter referred to as the *color-exposed vegetables.*
(ii) Orange bell pepper was not present on the place mats in the two *exposure* conditions, however pictures of differently colored bell peppers (e.g. yellow bell pepper) were printed on the mats in both *exposure* conditions (see Fig. 1a and b). Bell pepper is hereinafter referred to as the *kind-exposed vegetable.*
(iii) Yellow zucchinis were not presented on the place mats and neither were differently colored zucchinis (see Fig. 1a and b). Zucchini is hereinafter referred to as the *non-exposed vegetable.*

These different statuses were created to investigate whether exposure effects may generalize to other unexposed stimuli.

To comply with the usual presentation of these vegetables in school cafeterias, zucchini and bell peppers were served cooked while carrots and tomatoes were served raw and zucchini and carrots were sliced while tomatoes and bell peppers were cut into wedges. None of the vegetables were peeled.

At the beginning of the task a small piece of each vegetable was placed on small white plastic plates (pairs were presented simultaneously in a counterbalanced order). Children were told many foods were available and they could taste them all if they wanted in order to help the experimenter select food items that they liked for the cafeteria menu the following week. Each time the participant looked at or came closer to a pair of vegetables, the experimenter said "These are carrots (for instance), would you like to try them?". We labeled the different vegetables in this task to prime the corresponding category for children in order to investigate whether they were willing to accept a novel mode of presentation within a known category. As the four vegetables in the study are commonly served at school canteens, and because menus are announced verbally each day to the children by the cafeteria personnel, all children were familiar with their labels. The experimenter simply recorded for each child the number of tasted vegetables (i.e. put in the child's mouth, swallowed or not).

2.5. Statistical analysis

To test our first and second hypotheses (H1, H2), a linear mixed model was used with the number of atypically colored vegetables eaten as the outcome measure, because the intervention phase consisted of exposing children to atypically colored vegetables. The predictive variables of primary interest in this model were time (T0,T1), status of the vegetable (*color-exposed, kind-exposed, non-exposed*), condition (*C,SE,DE*), and CFRS scores. Interaction between time and other primary variables, as well as interaction between CFRS scores and other primary variables were also added in the

[1] This protocol used by Rioux and colleagues (under review) was based on research on category-based induction (Badger & Shapiro, 2012; Fisher, Godwin, & Matlen, 2015; Gelman & Markman, 1986).

model as primary variables. Age, frequency of consumption and liking scores were predictive variables of secondary interest.

To test our third hypothesis (H3), a regression analysis was used with the difference between the number of atypically colored vegetables eaten at T1 and T0 as an outcome measure. The predictive variables of primary interest in this model were categorization scores, category-based induction scores, and CFRS scores and their interactions. Age and liking scores were predictive variables of secondary interest.

The significance level was set to 5% ($p < 0.05$). All statistical analyses were performed with the software R. 3. 2. 4., using the package "nlme".

3. Results

3.1. Evaluation at baseline

The characteristics at baseline (T0) of the children who fully completed the study are presented in Table 3. Children in the *control* condition were significantly younger than those in the other two conditions. Additionally, children in the *diverse exposure* condition ate atypically colored vegetables significantly less often at home, compared to the two other conditions.

3.2. Does simple and diverse visual exposure to vegetables lead to an increase in the consumption of this food category (H1 and H2)?

A linear mixed model was used with the number of atypically colored vegetables eaten (ranging from 0 to 4) as the dependent variable, time (T0, T1) and status of the vegetable (*color-exposed, kind-exposed, non-exposed*) as within-participants factors, and condition (*C, SE, DE*), age, CFRS score (measuring neophobia and pickiness), frequency of consumption, and liking scores as between-participants factors.

This analysis revealed a main effect of time, $F = 31.21$, $p < 0.0001$. Children were more willing to taste atypically colored vegetables at T1 ($M = 2.34$, $SD = 1.61$) than T0 ($M = 1.57$, $SD = 1.38$). No effect of the status of the vegetables was found (i.e. children ate the same amount of *color-exposed*, *kind-exposed,* and *non-exposed* vegetables).

An effect of the CFRS scores was also found, $F = 7.54$, $p = 0.0078$. Highly neophobic and picky children ate significantly fewer atypically colored vegetables than their counterparts (Spearman's correlation coefficient: $r = -0.22$, $p = 0.0067$, see Fig. 3, black continuous line). An interaction between CFRS scores and time was also found, $F = 12.30$, $p = 0.00060$, (see Fig. 3 dashed lines). The increase of eaten vegetables between post-test (T1) and baseline (T0) was greater for non-neophobic and non-picky children, than for highly neophobic and picky children (see Fig. 3, dashed lines).

In support of the first hypothesis (H1), a main effect of the condition was revealed, $F = 7.69$, $p = 0.0010$, and more interestingly so was an interaction between condition and time, $F = 6.07$, $p = 0.0027$ (see Fig. 4). A post hoc analysis indicated that at T0 the number of atypically colored vegetables tasted in each condition did not differ significantly ($ps > 0.05$). The post hoc analysis also revealed that in support of our first hypothesis, in the *simple exposure condition* the number of atypical vegetables tasted at T1 ($M = 3.09$, $SD = 1.44$) was significantly greater than at T0 ($M = 1.75$, $SD = 1.42$, $p = 0.019$).

However, contrary to the second hypothesis (H2), this post hoc analysis revealed that post-test (T1), the children in the *simple exposure condition* ate significantly more atypical vegetables ($M = 3.09$, $SD = 1.44$) than children did in the *diverse exposure condition* ($M = 1.46$, $SD = 1.53$, $p = 0.0014$). Children in the *diverse exposure condition* did not significantly increase their consumption at T1 from T0.

Lastly, the analysis also revealed a main effect of the liking for the four vegetables in the tasting task, $F = 4.19$, $p = 0.049$. Children ate more atypically colored vegetables when they liked those vegetables (as attested by a positive and significant Spearman's coefficient, $r = 0.25$, $p = 0.0026$).

3.3. Does visual exposure to vegetables lead to an increase in the consumption of this food category through a mediating effect of the increase in ease of categorization (H3)?

Contrary to hypothesis 3, no significant increase in the cognitive performances of children between baseline and post-test were found ($ps > 0.05$ for both categorization performance and category-based induction performance as attested by paired Wilcoxon's signed-rank test). Additionally, within each experimental condition, we did not find any significant increase in the cognitive performances of children between baseline and post-test (all $ps > 0.05$). As categorization and category-based induction performances at baseline were significantly correlated with performances post-test (as attested with Spearman's coefficients both $ps < 0.05$), we averaged the scores across time. Each child was therefore assigned a single *categorization score* ($M = 0.35$, $SD = 0.49$) and a single *category-based induction score* ($M = 0.48$, $SD = 0.28$).

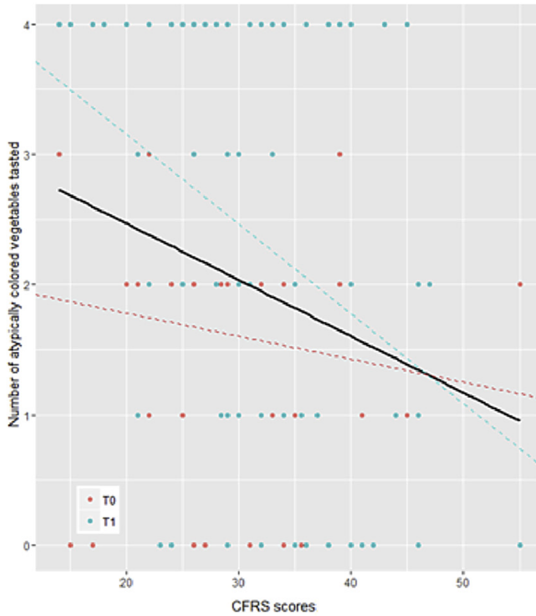
We evaluated the moderator effect of cognitive performances on the increase in willingness to try atypically colored vegetables in the *simple exposure condition.* We ran a linear regression analysis with the difference in number of atypically colored vegetables eaten at T1 and T0 (ranging from −4 to 4) as the dependent variable, and with categorization and category-based induction scores, CFRS scores, age, and liking scores as predictive variables.

This model only revealed a significant effect of categorization scores, $F = 4.22$, $p = 0.054$ (see Fig. 5). As presented in Fig. 5, the partial correlation between categorization performance and the difference in number of atypically colored vegetables eaten at T1 and T0, corrected for age, was significant (as attested by Spearman's partial correlation coefficient, $r = 0.42$, $p = 0.032$). We corrected for age, because there are age differences in categorization performance on this kind of forced-sorting task (Rioux et al., 2016).

Table 3
Characteristics of the study population at baseline.

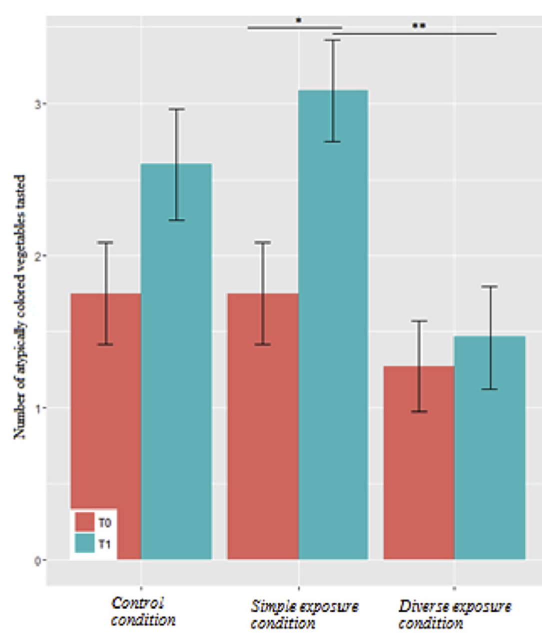
	Control condition (n = 20)	Simple exposure condition (n = 24)	Diverse exposure condition (n = 26)
Female/male *(n)*	10/10	13/11	17/11
Age *(mo)*	46.56 (±6.45)[a]	52.21 (±9.45)[b]	54.08 (±8.08)[b]
Liking	4.7 (±0.84)	4.46 (±1.56)	4.48 (±1.06)
Frequency of consumption at home	2.11 (±0.79)[b]	2.19 (±0.64)[b]	1.55 (±0.51)[a]
CFRS scores	31.80 (±7.10)	31.96 (±8.94)	31.69 (±8.85)
Categorization performance	0.44 (±0.62)	0.48 (±0.81)	0.45 (±0.62)
Induction performance	0.46 (±0.35)	0.52 (±0.30)	0.54 (±0.31)

Note: values are means ± SD. Means with a different common letter differ, $p < 0.05$.



Note. The Spearman coefficient correlation indicated a significant and negative correlation between children's eating patterns and their food neophobia and pickiness levels (r = -0.22, p = 0.0067) across time (black line). The correlation was not significant atT0 (r = -0.11, *ns,* blue dashed line) and significant at T1 (r = -0.33, p = *0.0045*, red dashed line).

Fig. 3. Children's willingness to taste atypically colored vegetables as a function of their food neophobia and pickiness scores (CFRS scores).
Note. The Spearman coefficient correlation indicated a significant and negative correlation between children's eating patterns and their food neophobia and pickiness levels ($r = -0.22$, $p = 0.0067$) across time (black line). The correlation was not significant atT0 ($r = -0.11$, *ns,* blue dashed line) and significant at T1 ($r = -0.33$, $p = 0.0045$, red dashed line). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

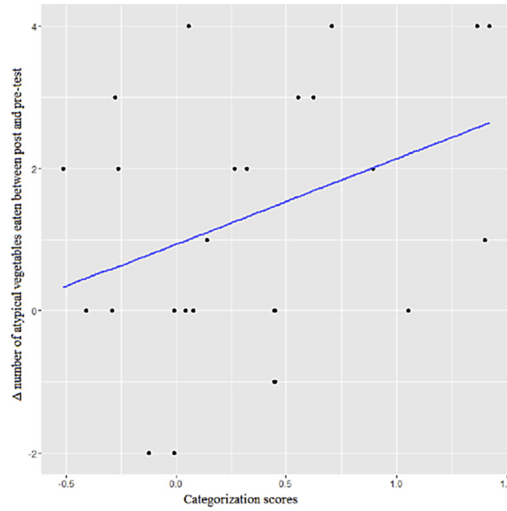


Note. Significant differences between the age groups are marked * for $p < 0.05$ and ** for $p < 0.001$.

Fig. 4. Children's willingness to taste atypically colored vegetables as a function of experimental condition and time.
Note. Significant differences between the age groups are marked * for $p < 0.05$ and ** for $p < 0.001$.

4. Discussion

The goal of the present study was to explore further the potential for visual exposure and to investigate the mechanisms responsible for its impact. We tested the effectiveness of an intervention among children, who were exposed to different pictures of



Note. The Spearman coefficient correlation indicated a nearly significant and positive correlation between categorization performance and the difference in number of atypically colored vegetables eaten, between T1 and T0 ($r = 0.37$, $p = 0.069$).

Fig. 5. Children's change in willingness to taste atypically colored vegetables between T1 and T0 as a function of categorization score.
Note. The Spearman coefficient correlation indicated a nearly significant and positive correlation between categorization performance and the difference in number of atypically colored vegetables eaten, between T1 and T0 ($r = 0.37$, $p = 0.069$).

vegetables, compared with a control group of children, who were not exposed these pictures.

4.1. Does simple visual exposure to vegetables lead to an increase in the consumption of this food category (H1)?

In support of our first hypothesis, results indicated that children in the *simple exposure* condition did increase their consumption of exposed vegetables after the intervention period. Indeed, in this condition, children consumed significantly more atypically colored vegetables at post-test than at baseline (see Fig. 4). This finding is in line with the claims of Houston-Price, Butler and colleagues (2009) and Osborne and Forestell (2012): looking at food pictures increases children willingness to taste these particular foods.

Interestingly, we also found that visual exposure effects were not tied to the exposed stimuli themselves. Indeed, we did not find any significant effect of the status of the vegetables. Children in the *simple exposure* condition, significantly increased their consumption of *color-exposed vegetables* (green tomatoes and purple carrots) as well as *kind-exposed vegetables* (orange bell peppers) or even *non-exposed vegetables* (yellow zucchinis), between pre and post-test. Therefore, they ate not only more *exposed vegetables* but also more atypically colored (and thus novel) vegetables in general, and visual exposure effects generalized to other, unexposed stimuli. This result is in line with Birch and colleagues' finding (1998) and Tuorila and colleagues' finding (1994), since these authors observed that changes due to exposure were not restricted to the target food. It suggests to us that the changes we observed in children's eating behaviors may be associated with their more mature representations of the exposed category rather than the exposed instance *per se*. For instance, it is possible that because we presented children with novel colors of familiar kinds of vegetables, they understood that the same food may undergo perceptual feature changes between servings.

However, in contrast to these promising results, we found an effect of children's CFRS scores. Highly neophobic and picky children ate significantly fewer atypically colored vegetables than their counterparts. Additionally, we found that the increase in eaten vegetables between post-test (T1) and baseline (T0) was greater for non-neophobic and non-picky children, compared to highly neophobic and picky children (see Fig. 3, dashed lines). This is consistent with numerous studies showing significant negative correlation between neophobia assessed through questionnaires and willingness to try novel foods (Laureati, Bergamaschi, & Pagliarini, 2015; Loewen & Pliner, 2000; Pliner, 1994). At first glance, this result reinforces findings indicating that children with high food neophobia and pickiness are less responsive to exposure interventions (Caton, Ahern, & Hetherington, 2011; De Wild, Cees de Graaf, & Jager 2016; Zeinstra, Kooijman, & Kremer, 2016). Nevertheless, within the *simple exposure* condition, the significant increase in atypically colored vegetables eaten was not affected by children's CFRS scores (as attested by the second regression analysis). This suggests that visual exposure interventions are suitable for these children. It is important to note that we observed the same pattern of results for liking. Indeed, while across conditions children ate more atypically colored vegetables as a function of their liking for the vegetables, the success of the intervention in the *simple exposure* condition was irrespective of children's liking (as attested by the second regression analysis). Taken together, these promising findings suggest that, in line with our first hypothesis, children (both with high and low food neophobia and pickiness) might be more easily persuaded to try a new vegetable if they have seen a picture of this vegetable, or another vegetable, first.

4.2. Does diverse visual exposure to vegetables lead to a greater increase in the consumption of this food category (H2)?

Contrary to our second hypothesis, results indicated that children in the *diverse exposure* condition did not increase their consumption of atypically colored vegetables after the intervention period. This absence of any significant increase in vegetable consumption was not in line with the recent study conducted by Houston-Price, Butler, et al. (2009) which showed that offering children different presentations of a food could lead to greater interest in that food.

We assumed that this condition would be more effective to increase vegetable consumption because neophobic children tend to rely on color similarity to draw induction in the food domain (Rioux et al., under revision). They should then benefit from an exposure intervention that exposes them to diverse colors for given food items. They would learn that color similarity should be disregarded, in favor of labels, when making predictions and consumption choices about food items. We have two hypotheses to explain the absence of a significant increase in vegetable consumption. First, in each condition, children saw the place mats for only eight days to avoid boredom effects (Wadhera & Capaldi-Phillips, 2014). Thus children in the *diverse exposure* condition only saw each instance of atypically colored vegetables twice (i.e. they saw green tomatoes for two consecutive days, then they saw yellow tomatoes for two days etc.). Comparatively, children in the *simple exposure* condition saw each vegetable eight times (i.e. they saw the green tomatoes for eight days). There is no consensus on the number of exposures needed to increase the consumption of a food item, especially for visual exposure. For instance, Houston-Price, Burton and colleagues (2009) did not find any enhanced interest for exposed food after 2–5 or 6–8 readings of a food picture book. However, most studies argue in favor of a number greater than two for toddlers (Birch et al., 1987; Sullivan & Birch, 1990). It is possible that eight exposures for each instance of colored vegetables would have led to positive effects on consumption as well in the *diverse exposure* condition.

Another plausible explanation is that, by revealing to children that vegetables can have different colors, we did succeed in lowering the predictive value of color for inductive reasoning in the food domain. However, as vegetables were not labeled during the intervention phase, we failed to provide alternative reliable cues, such as labels, to support categorization and category-based induction. Indeed, during the 2-week exposure intervention, the place mats were simply set on the table in the cafeteria. An experimenter was present to ascertain whether children paid attention to the mats by telling them “Look at the different vegetables you have on the mats! Look they have different colors!”, but did not name the five vegetables depicted on the mats. Even if we named the vegetables during the individual WTV task, it is possible that by lowering the predictive power of color during the intervention, we unwittingly increased the children's state of uncertainty about the atypically colored vegetables. As a possible consequence children picked the vegetables that were familiar to them at post-test, namely the typically colored ones, to be sure of the consequences of ingestion. Tuorila et al. (1994) accordingly found that label information reduces uncertainty about the identity of a novel food and initially reduced negative responses to this food. Similarly Morizet, Depezay, Combris, Picard, and Giboreau (2012) found that 8- to 11-year-old children more often chose the familiar presentation of a familiar vegetable when no label information was given. Conversely, the availability of a label led to an increase in consumption of the new presentation of a familiar vegetable (Morizet et al., 2012). The greater correlation between CFRS scores and the number of atypically colored vegetables eaten at *post-test, compared to baseline* (see Fig. 3, red dashed line) may support this hypothesis. Neophobic and picky children, who supposedly reject a particular food item because there is not an acceptable similarity between the item and its representation in their mind (Brown, 2010; Dovey et al., 2008; Lafraire et al., 2016; Rioux et al., 2016), were therefore negatively impacted by this increased uncertainty about the predictive power of color. Whether this type of diverse exposure intervention would be effective if the labels were provided during the exposure manipulation remains to be seen.

4.3. *Does visual exposure to vegetables lead to an increase in the consumption of this food category through a mediating effect of an increase in ease of categorization (H3)?*

Contrary to our third hypothesis, no significant increase in the cognitive performances of children (categorization and inductive performances) between baseline and post-test were found. We have two interpretations for this non-significant result. First, it is very likely that a 2-week exposure intervention was too short to significantly increase children's category content and categorization performance. Another explanation could be that our cognitive tasks were not sensitive or powerful enough to detect changes in children's cognitive performances. Therefore we can't draw conclusions about the potential mediating role of an improvement in cognitive performances on the enhanced consumption of vegetables in the *simple exposure* condition.

Nevertheless, results revealed a moderator effect of categorization performance on the increased consumption of vegetables. Indeed, in the *simple exposure* condition, in which we found a positive effect of visual exposure, children with better categorization performance increased their consumption between pre and post-test significantly more. For instance, the children with the highest categorization scores ate three more atypically colored vegetables at post-test than at baseline (see Fig. 5). Comparatively, the children with the lowest categorization scores ate roughly the same number at baseline and post-test (see Fig. 5). This result is in line with Rioux and colleagues' study, showing that children with good categorization performance had low food neophobia and pickiness (Rioux et al., 2016). This finding also reinforces the cognitive approach of the mere exposure effect (Bornstein & D'Agostino, 1994; Lafraire et al., 2016): even if we failed to increase the ease with which these vegetables are categorized with our exposure manipulation, we nonetheless showed that an ease of categorization led to a larger impact of the exposure manipulation, that resulted in a greater consumption of the four novel vegetables in the simple exposure condition. We are confident that with other visual types of exposure manipulations (for instance more active exposure or for a longer period) an ease in categorization could be revealed. Indeed in a recent study conducted by Mustonen, Rantanen, and Tuorila (2009), ameliorations of young children's cognitive performances (assessed via odor recognition and naming) were found, after a several-month sensory education program that exposed children to different food odors.

Finally, it is interesting to note that, children's categorization performance moderated their increase in vegetable consumption, but their inductive performance did not. The present result added a piece to the puzzle of the cognitive mechanisms underlying food neophobia and pickiness. Food neophobia and pickiness occur mainly at the mere sight of foods. This led some authors to hypothesize that rejections of fruits and vegetables are partly the consequences of an immature categorization system (Brown, 2010; Dovey et al., 2008; Lafraire et al., 2016; Rioux et al., 2016) that does not support the shift toward a focus on category membership for induction (Rioux et al., under revision). Two of the hallmarks of a mature categorization system are the ability to (i) recognize and organize into categories the stimuli in our environment and (ii) to make category-based inductions based on the knowledge that different items belong to the same or related categories. The present result suggests that food rejection behaviors seem to arise from an immature categorization system that does not recognize and organize into categories the stimuli in our environment. Focusing on the ease of categorization could be an efficient manner to tackle food neophobia and pickiness and to enhance the positive impact of visual food exposure.

4.4. Limits and perspectives

There are a number of shortcomings that could usefully be addressed in future research. First, our study did not include any long term follow-up. Therefore it is not clear whether the improvement in children's consumption was sustained over time. This is a question of importance as a recent review pointed out that few existing interventions are effective enough to increase vegetable consumption in children, especially in the long run (Appleton et al., 2016). Second, the number of exposures was chosen based on the existing literature and for practical reasons, but it may have led to the absence of positive effects in the color exposure condition. Further research is needed to establish how many picture encounters are required to trigger a positive attitude toward an exposed food. Finally, in the present study, children underwent a passive and short exposure experience. An experimenter was present to draw children's attention to the mats, but they were visible for a short period of time, namely just before lunch started and during dessert, because a plate was hiding the pictures for the rest of the lunch. It will be of interest to investigate the effect of a more active exposure manipulation, for instance if the children use the place mats for coloring. Such a strategy is in line with recent findings (De Droog, Van Nee, Govers, & Buijzen, 2017; De Droog et al., 2014). Indeed De Droog et al. (2014; 2017) found that picture books were particularly effective to increase the consumption of exposed vegetables when children were actively involved in the reading sessions (answering questions about the story etc.).

On the other hand, particular strengths of the intervention include its simplicity and its effectiveness with highly neophobic and picky children, while several other exposure manipulations failed to increase the consumption of novel foods for this population (De Wild, de Graaf, & Jager, 2016; Zeinstra et al., 2016). In addition to the measurable effects, the intervention appealed to school and cafeteria staff members because they were present during the exposure intervention and helped us design this study. It is recognized that some feeding strategies seem counterproductive (e.g. the use of food reward, see DeCosta, Moller, Frost, & Olsen, 2017) and school and cafeteria staff members who play an important role in children's development could profit from exchange with scientists working on children's food behaviors.

5. Conclusion

Our findings added to the rising body of evidences in favor of the positive effect of mere visual exposure. Vegetable pictures might help parents to deal with some of the difficulties associated with the introduction of novel vegetables (or novel preparations of familiar vegetables). Our findings also suggested that focusing on conceptual development could be an efficient manner to tackle food neophobia and pickiness and to enhance the positive impact of visual food exposure, as demonstrated by the moderator effect of categorization performance on vegetable consumption.

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GENERAL DISCUSSION

The two strongest psychological barriers to increase a child's dietary variety seem to be food neophobia and pickiness (Dovey, Staples, Gibson, & Halford, 2008). Numerous studies have uncovered negative associations between food neophobia or pickiness and intake of fruits and vegetables (Fletcher et al., 2017; Perry et al., 2015). It is therefore essential to understand the mechanisms underpinning these two kinds of food rejections to promote the adoption of healthy eating behaviors among preschoolers.

Food rejections are thought to be an adaptive solution to the problem of food selection (referred as the *omnivore dilemma;* Rozin, 1979) because they prevent children from ingesting potentially poisonous foods. On the other hand, a food categorization system, allowing for a food/nonfood distinction, discrimination between different foods, and inferences of edibility, enables efficient sampling of food resources and enrichment of children's food repertoire. If food rejections and food categorization are the two complementary facets of the omnivorous dilemma, it is reasonable to suspect interplays between the two mechanisms.

In this context, the fourfold objective of the present thesis was:

(a) To develop and validate a hetero-assessment scale to measure food neophobia and pickiness for French children as young as 2 years of age;

(b) To clarify the concept of pickiness and to provide an insight into the relationship between food neophobia and pickiness;

(c) To directly investigate the relationship between food categorization development in young children and their food neophobia and pickiness;

(d) To design an intervention, exploiting the empirical evidence on the relationship between food categorization and food rejections, to positively influence children food rejections.

The present chapter summarizes, for each objective successively, the main findings and their interpretations and finally, presents some perspectives.

1. A validated tool to measure food rejections in young French children

To propose a reliable tool to measure food neophobia and pickiness in toddlers and preschoolers, all the properties expected of any psychometric instrument were measured: internal consistency, test-retest reliability, construct, convergent, discriminant and predictive validity (De Lauzon-Guillan et al., 2012; Ritchey, Frank, Hursti, & Tuorila, 2003; Vallerand, 1989) (see Table 1). To propose a practical and easy-to-administer tool, a short scale was designed, capturing both neophobia and pickiness without including superfluous items.

The Child Food Rejection Scale (CFRS), displayed good psychometric properties (see Table 1) and is short to administer (6 items measuring neophobia and 5 items measuring pickiness).

Table 1: Psychometric properties of the CFRS.

Internal consistency	Test-retest reliability	Convergent validity	Divergent validity	Predictive validity
Cronbach's α = 0.87	*r* = 0.90*** between test and retest scores	*r* = 0.81*** between FAS and CFRS scores	*r* = 0.33*** between RCMAS and CFRS scores	*r* = 0.48* between food choices and CFRS scores

Note. * $p < 0.05$. *** $p < 0.001$.

For instance, internal consistency measured with Cronbach's α was good, with a value comparable to those found in previous research on children' food neophobia and pickiness. Rubio, Rigal, Boireau-Ducept, Mallet and Meyer (2008) found a Cronbach's α of 0.84 for their neophobia scale. Rigal, Chabanet, Issanchou and Monnery-Patris (2012) found a Cronbach's α of 0.74 for their pickiness scale.

However, the correlation between CFRS scores, assessed by caregivers, and children food choices was moderate (but within the range of those previously found by studies assessing the predictive validity of the FNS; see Rubio et al., 2008). To test the predictive validity of the CFRS children were asked to choose among a set of pictures, the foods they were willing to taste later at the canteen (chapter 5), while the use of real foods might have led to a stronger correlation (chapter 5). However, in the last experiment, using a similar food choice paradigm but with genuine foods, a similar (moderate) correlation between CFRS scores and willingness to taste new foods was found (chapter 8).

Three further hypotheses to explain these moderate correlations can be proposed. First, the food choice task used to assess the predictive validity of the CFRS only considered one aspect of pickiness, that a picky child is likely to sort his/her food. A more suitable food choice task should also consider other aspects of pickiness, for instance present children with foods varying in texture, because the item "my child refuses certain foods due to their texture" loaded strongly on the pickiness dimension.

A second hypothesis is that caregivers may not be perfect predictors of their children's food behaviors, because they cannot be acquainted with all their children's eating practices. They also may not always understand the basis of food rejection. Concerning food neophobia, previous studies have found medium correlation between parental and children report of neophobia (Pliner, 1994). To our knowledge, no studies have evaluated this correlation for pickiness, but it should be moderate as well. While it is easy for caregivers to know whether their children sort their food, it is difficult to identify when a food item is rejected because of its texture.

Finally, food neophobia and pickiness probably are behavioral *dispositions* (chapter 1). To possess a dispositional property is not to be in a particular state, but to be bound or liable to be in a particular state (chapter 1). In other terms, the manifestation of a behavioral disposition is never guaranteed; therefore, the correlation between CFRS scores and food rejection behaviors is necessarily moderate.

Nonetheless the CFRS represents an efficient tool for studying food rejection dispositions in young French children. This scale was successfully used in the three subsequent experiments of the present thesis. In each experiment, the same findings were found: within the 2-6 age range, food rejections did not vary with age, or according to children's gender. This is consistent with the view put forward by Addessi, Galloway, Visalberghi and Birch (2005) or Cooke, Wardle and Gibson (2003), that food rejections remain stable during early childhood, once they appear.

2. A new apprehension of the neophobia-pickiness relationship

2-1- Refining the definition of pickiness

The preliminary experiment ahead of the validation of the CFRS allowed us to define more clearly the concept of pickiness (chapter 5). An initial set of 21 items to assess pickiness was proposed. These items were mostly created for the experiment and were based on the diverse definitions of pickiness found in the literature. Few items were also retrieved from existing pickiness questionnaires (the Children's Eating Behavior Questionnaire, CEBQ, Wardle, Guthrie, Sanderson, & Rapoport, 2001; the Children's Eating Difficulties Questionnaire, CEDQ, Rigal, et al., 2012). Exploratory factorial analysis (EFA) allowed us to examine whether these

21 items loaded on the same dimension (i.e., measure the same phenomenon). The EFA revealed that 5 items loaded on the same dimension, assumed to be the pickiness dimension (see Table 2). This was confirmed with a confirmatory factor analysis (CFA) (chapter 5).

Table 2: Items of the pickiness subscale and their factor loadings from the confirmatory factor analysis.

Item	Factor loading of the CFA
1-*My child refuses certain foods due to their texture*	0.62
2-My child rejects certain foods after tasting them	0.42
3-My child can accept one food one day and refuse it the next day	0.43
4-My child sorts his/her food on the plate	0.72
5-My child can eat some foods in large amounts and completely reject others	0.60

The first two items concern the rejection of certain textures (1) and the point of rejection of the food (2), and echoed the currently used definition of pickiness (Smith, Roux, Naidoo, & Venter, 2005; Taylor, Wernimont, Northstone, & Emmett, 2015). Pickiness is the rejection of certain food textures, and contrary to neophobia, can occur after the tasting step.

The item regarding the acceptance depending on the day (3) reflects some authors' hypothesis that caregivers misunderstand food familiarity and do not perceive that some changes in the recipe can make an already accepted food, new to their child (Brown, 2010; Rigal, 2010).

The item regarding sorting food (4) is similar to an item in the neophobia subscale of the CFRS ("my child won't try a novel food if it is touching another food he/she does not like") and refers to the contamination effect, a fundamental feature of disgust (Brown & Harris, 2012). From 3 years of age, children show awareness of the transfer of properties from one item to another (Rosen & Rozin, 1993) and the proximity of the contaminant is enough to reduce the liking of an accepted substance (Toyama, 1999). The contaminant could be a disliked food, but also a new and thus potentially toxic food. In this case, sorting the food will be a strategy to avoid the risk of ingesting toxic foods. Therefore, pickiness may be associated to an increased disgust over foods, as neophobia (Brown & Harris, 2012; Martins & Pliner, 2006).

Finally, the item regarding food quantities (5) suggests that pickiness is dissimilar to a low enjoyment of food or a small appetite, as some researchers have argued (Levene & Williams, 2017; Wardle et al., 2001). For instance, in the CEBQ one item of the pickiness subscale is "my child is difficult to please with meal" (Wardle et al., 2001). This item was present in the preliminary version of the CFRS but subsequently removed during the ETA. The fact that pickiness is distinct from these other eating difficulties (low appetite, low enjoyment of food etc.) is in line with the study of Rigal and colleagues (2012) and draws food neophobia closer to pickiness.

Nevertheless, the pickiness subscale of the final CFRS is less robust than the neophobia subscale, because it has a lower consistency (Cronbach' α = 0.69), so further investigations are needed to pursue the clarification of pickiness.

2-2-Food neophobia and pickiness: two facets of the same fear of potentially toxic foods.

To provide an insight into the relationship between food neophobia and pickiness, an investigation of the factorial structure of the CFRS was conveyed. The confirmatory factorial analysis (CFA) revealed that the two-dimension model had the best fit indices, supporting the distinction between food neophobia and pickiness (chapter 5). This is not in line with Wardle and colleagues' who did not distinguish between neophobia and pickiness (2001) (see Fig. 10c).

The correlation between dimension 1 (assumed to represent food neophobia) and dimension 2 (assumed to represent food pickiness) was positive and strong ($r = 0.76$). A child with high food neophobia is likely to display high pickiness as well, and inversely, as proposed by Dovey and colleagues (2008) (see Fig 10a). A significant correlation between neophobia and pickiness subscales was repeatedly found in the different experiments conducted (Exp 2: $r = 0.\ 57$; Exp 3: $r = 0.58$; Exp. 4: $r = 0.54$). This is not in line with Galloway, Lee and Birch (2003) who proposed that the two concepts are clearly theoretically and behaviorally distinct (see Fig 10b).

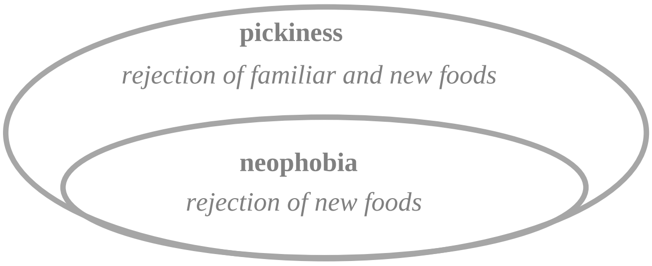
In agreement with the first hypothesis of the present thesis, the results suggest that *theoretically* speaking, food neophobia and pickiness capture a same kind of *fear for new and potentially toxic foods*. Indeed, as food neophobia, pickiness presents at least one signature feature of a phobia revealed by item 4: an increased disgust over foods. Texture rejection, revealed by the factorial analysis to be an important component of food pickiness (item 1), prevents the ingestion of potential toxic foods (as texture can inform of

the decay of a food, Martins & Pliner, 2006). Finally, what is thought to be rejection of familiar foods is probably rejection of foods perceived as new for children (item 3, Rigal, 2010).

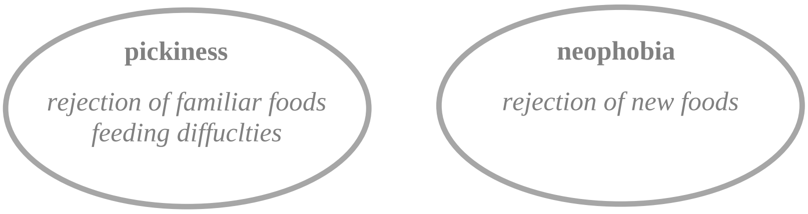
Nevertheless, neophobia and pickiness appear as two *behaviorally* distinct constructs (as revealed by the factorial analysis of the CFRS). Indeed, although the motivation for rejection seems to be the same, caregivers appear to distinguish rejection due to texture from others and rejection after the tasting step. (see Fig.10d).

Figure 10: Different views of the relationship between food neophobia and food pickiness.

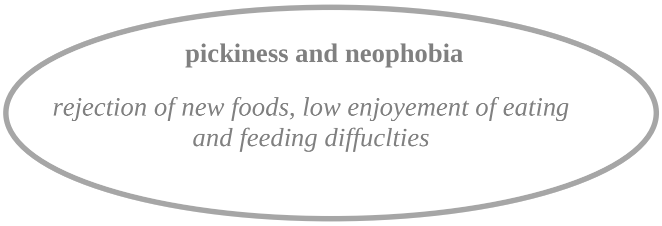
a.



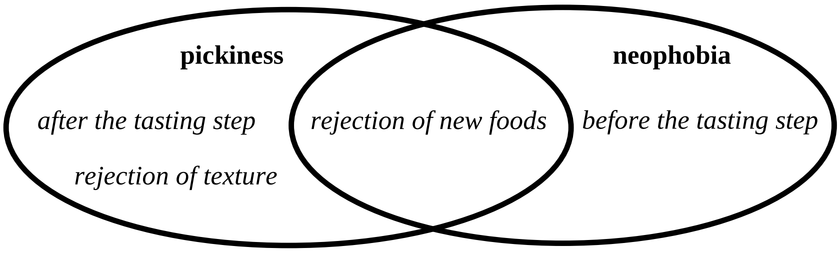
b.



c.



d.



3. A better understanding of the cognitive factors involved in food rejections

3-1- The importance of color in the food domain

To test for the influence of color typicality in the food domain, in both the categorization task (chapter 6, Exp. 2, appendix 1) and category-based induction task (chapter 7, Exp. 3, appendices 2-5), typically and atypically colored food stimuli were used. In the categorization task, children had to sort pictures of green zucchinis, but also yellow zucchinis. In the category-based induction task, children had to generalize knowledge from green zucchinis to orange or purple carrots.

In the categorization task, the results indicated that color *per se* influenced categorization performances, but also, and to a greater extend, color typicality (chapter 6): color typicality was the most salient variable predicting the hit percentage of a given vegetable. Typically colored vegetables (e.g., green zucchinis) were more often put in the vegetable box than atypically colored ones (e.g., yellow zucchinis).

The literature on the importance of color over shape information in the food domain principally considered the importance of color *per se* (Foroni, Pergola & Rumiati, 2016; Lavin & Hall, 2001; Shutts, Condry, Santos, & Spelke, 2009). Color is a valuable cue in the food domain since it informs about the maturity of a food and its energy value: red nuances in natural foods (e.g., fruits) generally indicate high energy content while green nuances generally indicate low energy content (Foroni et al., 2016).

The results of the present thesis comfort the importance of color *per se* in the food domain but also revealed that the contribution of color information is to convey typicality information, supporting the third hypothesis.

However claim that color conveys *more* information about typicality than shape in the food domain cannot be made. Indeed, the shape was held constant across different presentations of a given vegetable (e.g., all the zucchinis - green, yellow etc. - were cut in slices; chapter 6). The extent of shape typicality's contribution to fruit and vegetable categorization and potential subsequent acceptance remains to be investigated. A parallel study, in which color is held constant and children are proposed different shapes for a given vegetable, is needed to investigate more closely the importance of shape cues in the food domain.

The results did not reveal any color typicality effect in the category-based induction task (chapter 7). This finding is possibly due to the fact that, overall, children chose the color-match fruit to generalize knowledge, and did not draw attention to the differently colored vegetable, no matter its color.

After a close investigation of the pattern of responses of non-neophobic children only (who did not display a bias to use color similarity to draw induction), a tendency to obtain better performances when the vegetable picture test was typically colored compared to atypically colored was observed (60% of good answers vs. 55%, p = 0.06). Further research on the importance of color typicality in food induction is therefore required with older children, who have a more mature food categorization system.

3-2 The development of food categorization during the sensitive period for food rejections

The sensitive period for food neophobia and pickiness is 2-to 6-years of age (chapter 1). Few studies have investigated the developmental characteristics of children's *food* categorization system during this sensitive period. From these few studies, it seems that a rapid change occurs around 2 years of age (chapter 2).

The results are in line with the findings that improvements appear in the child's food categorization system during this age range (Brown, 2010; Lafraire, Rioux, Roque, Giboreau, & Picard, 2016). A clear developmental effect in food categorization performances was found (chapter 6, chapter 8). When asked to sort pictures of fruits and vegetables, 2-to 4-year-old had better than chance performances; they were significantly outperformed by 4-to 6-year-old, who were themselves outperformed by adults (chapter 6). This developmental effect was also revealed in the last experiment (chapter 8). Using a similar forced sorting task with a new sample of 2-to 6-year-old, a positive and nearly significant correlation between age and categorization performances was found ($r = 0.22, p = 0.064$). These results suggest that children's food categorization system is improving during this age period (2-6 years of age). Yet, at 6 years of age, the food categorization system is still under construction.

The improvement of categorization performances with age in both experiments (chapter 6, chapter 8) was due to a diminution of the number of false alarms (i.e., fruit pictures put in the vegetable box), rather than an augmentation of the number of hits (i.e., vegetables pictures put in the vegetable box). While both younger and older children had hit rates around 74%, there was a clear fall in the mean false alarm rate for older children (from 44% to 29%, chapter 6). Comparable results were found in the fourth experiment (chapter 8). Only the number of false alarm was significantly correlated with age ($r = -0.29, p = 0.015$, chapter 8).

Children are familiar with the fruit and vegetable categories and effectively sort items from these two categories by 6 years of age (chapter 6, chapter 8). Nevertheless, it seems that 2-to 6-year-old children did not systematically rely on these taxonomic categories when making predictions about new foods (chapter 7, chapter 8). In the third experiment (chapter 7), children were told a novel property about a vegetable target picture and asked to

generalize this property to one of two test pictures (another vegetable or a color-match fruit). Contrary to adults, they tended to generalize the novel property based on color similarity, when perceptual information was given (below chance performances in the *word-and-picture* condition, chapter 7). Comparable findings were found in the last experiment (chapter 8).
However, when children only heard the name of the foods (and did not see any pictures, i.e. in the *word-only* condition, chapter 7) they performed almost above chance level. This suggests that children knew the corresponding categories of the different foods presented, but they were more likely to rely on color similarity to generalize knowledge when this information was available.

These results run counter to reports suggesting an initial tendency to rely on taxonomic category membership to draw inductive inferences in the natural kind domain (Gelman & Markman, 1986; Welder & Graham, 2001). In Gelman and Markman's seminal experiment (1986), children from 4-year-old relied on super-ordinate categories to draw inductive inferences in the natural kind domain, even when perceptual information was given.
It is possible that in the food domain perceptual properties, and color properties in particular, are more predictive than in other subdomains of the natural kind domain (such as the animal subdomain). In fact, humans seem to be able to extract from color properties relevant pieces of information such as energy density (Foroni et al., 2016). Importantly, this pattern does not emerge with nonfood items such as animals or flowers or with artifacts (Foroni, et al., 2016).
Supporting this view, in a follow up experiment conducted (data not published), 2-to 4-year-old children were proposed a similar category-based induction task, with two types of triad sets: triads containing new food pictures (food condition) and triads containing new artifact pictures (artifact condition). Within each condition the test picture that was perceptually similar to the target could be either similar in color or similar in shape. Considering only the triad sets where color similarity was investigated, children performed significantly better in the artifact condition and generalized knowledge based on taxonomic category membership 71% of the time. In contrast, children in the food condition generalized knowledge based on taxonomic category membership (and not based on color similarity) only 61% of the time.

Two of the hallmarks of a mature categorization system are the abilities:

(i) To recognize and sort into categories the different stimuli in our environment and;

(ii) To make predictions about new items, based on the knowledge of the category of these new items.

Therefore, it seems that by 6 years of age, children do not possess a fully mature *food* categorization system. Even if they could efficiently sort fruits and vegetables in distinct categories, they did not systematically use this knowledge to make predictions about new foods (chapter 6, chapter 7).

3-3 A plausible vicious circle

To directly investigate the relationship between cognitive development in 2-to 6-year-old children and their food rejections, a categorization task and a category-based induction task were proposed to children for whom caregivers filled the CFRS. The results from these two experiments provided the first empirical evidence of a negative relationship between children's food rejections and categorization and induction abilities (chapter 6, chapter 7).

First, categorization performances, assessed through the forced sorting task, and food rejections were significantly and negatively correlated ($r = -0.27, p = 0.014$, chapter 6). Highly neophobic and picky children performed poorly at the task, while low neophobic and picky children had good performances. More precisely, as the youngest children, highly neophobic and picky children had a high rate of false alarms, while, as the oldest children, low neophobic and picky children had a low rate of false alarms. These results were especially striking, given that food rejection scores were not correlated with age (chapter 6).

Second, category based induction performances and food rejections were also significantly and negatively correlated ($r = -0.19$, $p = 0.029$, chapter 7). Highly neophobic and picky children tended to generalize knowledge according to color similarity, while low neophobic and picky children tended to generalize knowledge according to taxonomic category membership (chapter 7). The correlation between food rejections and category-based induction performances was significant in the condition where children saw food pictures and heard the corresponding labels (i.e. *word-and picture* condition, $r = -0.35$, $p = 0.019$). This correlation was not significant in the condition when children just heard the labels (i.e. *word-only* condition, $r = -0.16$, $p = 0.31$). Finally, in a follow up study no correlation was found between food rejection scores and performances to a semantic space task. Highly neophobic and non-neophobic children performed equally to a semantic space task where they were asked to help us organize our groceries of fruits and vegetables, by placing food items similar in kind close together in the shopping trolley.

These results suggest that, compared with children with low rejection dispositions, highly neophobic and picky children were more likely to rely on color similarity to draw inferences when this information was available. They also suggest that differences between neophobic/picky and other children probably did not arise from differences in, either their semantic development, or their ability to rely on category membership when this was the only information available.

The second hypothesis of the present thesis was that food rejections are closely intertwined with the development of food categories and that food rejections are the behavioral consequences of an immature food categorization system (chapter 4). The results described above support this hypothesis. Highly neophobic and picky children possess a less mature food categorization system than their counterparts. They have poorer categorization performances (chapter 6) and they rely more on color similarity to draw inferences when this information is available (chapter 7).

The second hypothesis also proposed that rejection occurs when a presented food item is not subsumed under a certain category, because it has not an acceptable similarity with its prototype and that the immaturity of the food categorization system was characterized by a high number of misses (see Fig 11a). This hypothesis was in line with the research of Brown (2010) and Dovey and colleagues (Aldridge, Dovey, & Halford, 2009; Dovey et al., 2008). The results are not in accordance with this hypothesis, as the opposite pattern was found: highly neophobic children tended to make a high number of false alarms (i.e. they put fruit pictures in the vegetable box) rather than a high number of misses (i.e. they put vegetables in the fruit box) (chapter 6).

To explain this unexpected result, referring to the fact that neophobia is considered as a true phobia is enlightening (chapter 1). Food neophobia is associated with typical physiological fear responses, such as galvanic skin response and an increase in pulse or respiration rhythm (chapter 1). Moreover, pickiness is associated with an increased disgust over foods (chapter 5), a typical signature of phobias (Cisler & Köster, 2010).
Phobias have been linked with patterns of "vigilance" toward threat-related stimuli (Cisler & Köster, 2010). In adult populations, research has consistently found strong associations between phobias and attentional biases toward threatening visual stimuli (Cisler & Köster, 2010). For instance, persons who are phobic of snakes will tend to confound more easily a piece of wood

for a snake in a forest path, than persons who are not (Cistler & Köster, 2010). In other words, in phobias, the proper domain of the cognitive module ("all the information that it is the module's biological function to process"; Sperber, 1994, p.52) is thought to be *smaller* than the actual domain of the cognitive module ("all the information in the organism's environment that may satisfy the module's input conditions"; Sperber, 1994, pp.51-52, see. Fig 11b) because misses (a snake mistaken for a piece of wood) have more negative impact on reproductive success or survival than false alarms (a piece of wood mistaken for a snake). Therefore, immature cognitive modules associated to phobias (e.g., a snake detector module) are likely to generate a greater number of false alarms than misses (Pliner, 2008). The high rate of false alarms for highly neophobic and picky children could therefore reflect this visual attentional bias or "vigilance" toward threatening food items, namely vegetables. Indeed, vegetables are food items extremely prone to food rejections, possibly because they can contain secondary compounds toxic to humans (Cashdan, 1998).

Figure 11: Actual and proper domain of the food categorization system

Note. (a) Initial hypothesis. (b) Revised hypothesis empirically supported by the results. The continuous circle represents the ***proper domain*** *of the tomato category: all the tomatoes in our environment that should be accepted in the tomato category. The dotted circle represents the* ***actual domain*** *of the tomato category.*

Nevertheless, the results do not allow to discard Brown's (2010) or Dovey and colleagues' hypothesis (Aldridge et al., 2009; Dovey et al., 2008) that rejection may also occur when a presented food item is not subsumed under a certain category. The results found in the present thesis may be specific to vegetables because they are particularly threatening stimuli (they were often toxic in our ancestral environment, Cashdan, 1998). It is possible that children did not recognize the different food stimuli in the categorization task but categorized them nevertheless as vegetables as a default strategy, because it is better to mistake a nontoxic food for a (toxic) vegetable (i.e., to put all the pictures in the vegetable box) than to mistake a vegetable for a nontoxic food (i.e., to put all the picture in the fruit box). All the stimuli that fall in the actual domain of the particular vegetable category may be then rejected. It is possible that the same task, with safer food categories, would lead to results more in accordance to Brown or Dovey and colleagues' hypothesis. A given food would be accepted in a given category if it has an acceptable similarity with its prototype, and children with a high number of misses in the task may have a high score in the CFRS as well.

Finally, the results of these two experiments (chapter 6 and chapter 7) and the current literature, suggest that we might be facing a vicious circle (see Fig.12, right panel). Food acceptance depends on the maturity of the food categorization system. Immature food categories are likely characterized by poorer informational content, which in turn may lead to a high rate of false alarms and property generalization based on color similarity. Neophobic and picky children show such an immature categorization system (chapter 6, 7, see Fig. 12 right panel).

Food rejections exhibited by children, probably discourage caregivers to propose other vegetables or rejected food, because of a reluctance to waste food (Carruth, Ziegler, Gordon, & Barr, 2004; Cashdan, 1998; Heath, Houston-Price & Kennedy, 2011, see Fig 12 right panel).

However, the lack of exposure will lead to fewer learning opportunities in the food domain (and probably especially in the vegetable domain). This, in turn, has negative consequences on cognitive development, and probably more generally hinders the development of the food categorization system (see Fig. 12 right panel). Indeed, children's categorization and inductive abilities differ according to their experience and knowledge (chapter 2).

4. A promising intervention to decrease food rejections in ecological environments

To investigate the effects of visual food exposure and the mechanisms underpinning its effects, the effectiveness of an intervention among children who were exposed to different pictures of vegetables was tested (chapter 8, appendices 6-9).

The findings revealed that children did increase their consumption of exposed vegetables after the simple intervention period. When children saw the same place mat for eight days, they consumed more exposed vegetables at post-test than at baseline (chapter 8). This finding is in line with the findings of Houston-Price, Butler and Shiba (2009) or Osborne and Forestell (2012): looking at food pictures increases children willingness to taste these foods.
This positive effect of visual exposure was not tied to the exposed instances of vegetables but generalized to other unexposed stimuli. After being visually exposed to a yellow bell pepper, children were more likely to eat an orange bell pepper (new instance from the same basic level category) and a yellow zucchini (new instance from the same super-ordinate category).

Contrasting with these promising results, when children saw different place mats for eight days, they did not increase their consumption of exposed vegetables between post-test and baseline (chapter 8). A plausible explanation is that, by revealing to children that different exemplars of the same vegetables could have distinct colors, the *predictive value of color* for inductive reasoning in the food domain was lowered. As vegetables were not labeled during the intervention phase, no alternative reliable cues, such as labels, were provided to children to support induction. It is possible that by lowering the predictive power of color during the intervention, children state of uncertainty about the atypically colored vegetables was unwittingly increased. As a possible consequence, children picked the vegetables that were familiar to them at post-test, the typically colored ones.
The deeper investigation of the correlation between food rejection dispositions and the number of atypically colored vegetables eaten at post-test supported this hypothesis. It was in the *diverse exposure* condition (where children saw different place mats) that the vegetable consumption and the CFRS scores were the more robustly interrelated (r = -0.42, p = 0.062; r = -0.17, *ns*; r = -0.45, p = 0.024 respectively in the *control*, *simple exposure* and *diverse exposure* conditions). Neophobic and picky children, who supposedly reject a food item

because they cannot anticipate the consequences of ingestion (Brown, 2010; Dovey et al., 2008; Lafraire, Rioux, Giboreau, & Picard, 2016) were therefore negatively impacted by this increased uncertainty about the predictive power of color.

Finally, the results did not reveal significant increase in categorization performances of children between baseline and post-test. This findings does not support the fourth hypothesis that visual exposure is efficient to enhance food acceptance *because* it induces an ease in categorization.

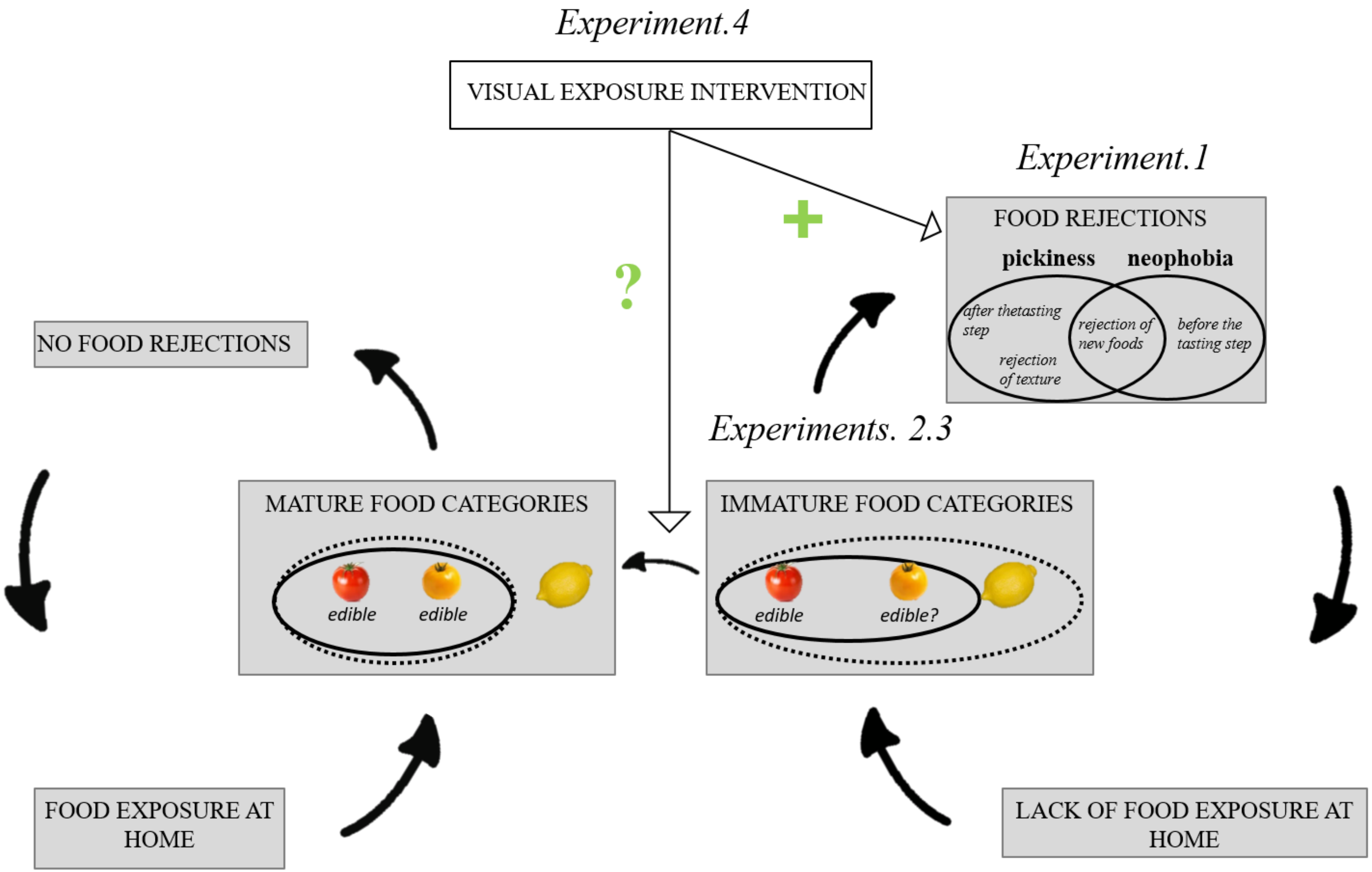
One possibility is that exposure did enhance cognitive performances but our cognitive tasks may not have been sensitive enough to detect any change in cognitive performances between baseline and post-test. A recognition task may have been a more suitable methodology. Indeed, in a recent study, Lumeng and Cardinal (2007) observed significant differences in cognitive performances between different food exposure conditions, using a recognition task.

In addition, the fact that positive effect of visual exposure was not tied to the exposed instances of vegetables, but generalized to other unexposed stimuli, suggests that, children acquired more mature categories after the intervention period. The changes observed in children eating behaviors may be associated with their finer and more mature representations of the exposed category rather than the one of exposed instance *per se*. For instance, it is possible that because children were presented with new color of familiar kinds of vegetables, they understood that the same food may undergo perceptual changes between servings.

Another possibility is that visual exposure did not enhance categorization performances (and inductive performances) but rather correspond to an attentional bias modification training (ABMT) usually used in phobias (Hakamata et al., 2010). Indeed, in ABMT, subjects are exposed to feared stimuli, so that attentional bias towards these stimuli is weakened and they can interpret or learn that feared object are safe (Hakamata et al., 2010).

Therefore, these results add to the promising body of evidence that visual exposure is effective to decrease food rejection behaviors. Looking at pictures of new foods increases children willingness to taste these foods. However, no conclusion can be drawn about the mechanisms underpinning the visual exposure effect (see Fig. 12). Future studies could use recognition tasks to investigate further the mechanisms behind visual exposure. For instance, an old-new recognition task could be used: children would be presented with target food pictures (presented also during the exposure phase) and distractor food pictures (new instances of food pictures). They would have to answer whether each picture is the same as, or different from the one seen in the exposure phase. Such a paradigm has been successfully used in a study conducted by Lumeng and Cardinal (2007). Differences in recognition performances were observed according to different exposure conditions.

Figure 12: Relation between food categories, food rejections and visual exposure.



5. Perspectives

The present thesis opened promising new avenues of research and began to shed light on the cognitive mechanisms underlying food rejections (both food neophobia and pickiness). These are preliminary conclusions and additional research is needed to gain a more complete understanding of the mechanisms that come to play.

Perspective 1: A bingo game to enhance cognitive performances

Results from the visual exposure intervention revealed that the intervention had a greater impact on children with high categorization performances. While this moderator effect of children categorization performances does not enable us to conclude about the mechanisms behind visual exposure, it does open promising avenue for future strategies aiming at overcoming food rejections. Training to enhance children conceptual development in the food domain could be designed, since it has been shown that short-term training can drive rapid knowledge change (Unger & Fisher, 2017). After such training, children will benefit more from simple visual exposure interventions. Such training may be more effective when they are proposed in the form of games. Coulthard and Ahmed (2017) proposed to children different training to enhance their cognitive performances: either a bingo game or a forced sorting task with pictures of fruits and vegetables. Subsequently, they proposed to children to taste new fruits and vegetables. The authors found that the bingo game was more effective than the sorting task, to enhance vegetable acceptance in a later session (Coulthard & Ahmed, 2017).

In a bingo game, children have to match pictures retrieved from a pile with pictures on their bingo board. A bingo game where the pictures from the pile and the pictures of the bingo board will be from the same basic level category but perceptually dissimilar could be designed. For instance, children will have to match a green tomato retrieved from the pile, with a picture of a red tomato on their bingo board. Children will then learn that food may undergo perceptual changes between servings.

Perspective 2: Validation of an English version of the CFRS

To enlarge the usability of the CFRS and to be able to compare children across cultures, further studies could adapt the CFRS for English children. The first step of such adaptation will be to translate in English the CFRS, with a process of back translation and then, to test the English version on a large native English speaker sample (Vallerand, 1989). Such process is engaged.

Two bilinguals, native English speakers, simultaneously translated the CFRS in English and then two bilinguals, French native speakers, translated it back in French. The original French version and the new French version were then compared to assure conformity. Once the English version was judged to be appropriate (because it led to a French version similar to the original CFRS), a sample of 19 bilinguals responded to the two versions (English and original French version) with a two-week interval. They were additionally asked to indicate whether the items were clear and correctly phrased. From their comments, the wording of the English version was slightly modified. The correlation between the score to the French original version and the final English version was high (r = 0.87, $p < 0.0001$). The English definitive version is currently tested on a large sample of English caregivers.

Perspective 3: Generalization to other domains

The results presented in this thesis are restricted to the development of the fruit and vegetable categories and generalization to other food categories or to other domains cannot be drawn. These categories were chosen because fruits and more especially vegetables are extremely prone to food rejections (Dovey et al., 2008). Further studies should investigate whether these results are generalizable to (i) other food categories, less prone to food rejections (such as starchy foods), (ii) other natural kind domains (such as the animal domain) and (iii) non-natural kind domains (such as the artifact domain).

In a recent follow up experiment (data not published) 2-to 4-year-old children were presented a category-based induction task, with two types of triad sets: triads containing new fruits and vegetables items (food condition) or triads containing new artifacts (artifact condition). Similarly to our previous results (chapter 7), children category-based induction scores and CFRS were significantly and negatively correlated in the food condition. Interestingly, these scores were not correlated in the artifact condition, suggesting that the results obtained in the present thesis might be at least specific to the natural domain.

Perspective 4: Natural versus Processed foods

In the literature on categorization and induction development, fruits and vegetables have been considered to fall into the broader domain of natural kind (Gelman, 1988). Accordingly, in the experiment conducted in the present thesis fruits and vegetables either whole or cut, but with minimal human transformation were used. However, food items that have been transformed by human activities seem to have more in common with artifacts (Foroni & Rumiati, 2017; Girgis & Nguyen, 2015). These transformed foods, not only look different than natural foods but can also have different predictive properties: green nuances generally indicate low energy content in fruits and leaves while caloric content is largely detached from color for artificially colored processed foods (Foroni et al., 2016).

From an evolutionary perspective, it is likely that the dietary patterns of our hunter-gatherer ancestors have shaped our minds in ways that continue to guide food categorization. Within a hunter-gatherer environment, foraged natural foods (e.g., fruits, vegetables) have been essential food sources (Ungar & Sponheimer, 2011). In contrast to the hunter-gatherer environment, the contemporary food environment is full of highly processed foods (e.g., pasta, candies). A recent neuropsychological review (Rumiati & Foroni, 2016) investigated how food is represented in our mind, by reporting how brain-damaged patients recognize food and nonfoods. The review revealed that some studies seem to indicate that food representations (irrespective of whether it is natural or processed) dissociate from representations of nonliving things such as kitchenware (e.g., De Renzi & Lucchelli, 1994). On the contrary, the review also revealed that some studies have shown that recognition of natural foods and living things (such as animals) dissociated from recognition of manufactured foods and artifacts such as tools (e.g., Hillis & Caramazza, 1991).

A promising perspective will be then to investigate, within the food domain, cognitive performances with very highly transformed food items and their relationships with CRFS scores. There is a blossoming literature investigating whether the distinction between natural and transformed foods is relevant for food evaluation and learning processes (Foroni & Rumiati, 2016, Nguyen & Girgis, 2015; Wertz & Wynn, 2014).

6. Conclusion

The different findings of the thesis are summarized in Fig. 12. The present thesis is one of the first research to investigate directly the connection between food rejection dispositions (both food neophobia and food pickiness) and cognitive development. This investigation revealed negative connections. While it requires further investigations, the thesis offers a contribution to the understanding of the development of food rejection during toddler and preschool ages, and provides some evidence for the four hypotheses. This contribution will be valuable to design interventions aiming at improving children eating habits.

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APPENDICES

Appendix 1: Consent form and parental questionnaire (Experiment 2)

Formulaire et autorisation à destination des parents
pour une étude sur les rejets alimentaires chez l'enfant (de 2 à 6 ans)

Contact scientifique : Camille Rioux, doctorante en psychologie cognitive
camille.rioux@institutpaulbocuse.com

Merci de bien vouloir nous retourner ce formulaire avant le **vendredi 5 juin**

Questions préliminaires :

i) **Prénom** et **nom** de l'enfant :

ii) **Date de naissance : ../../20..**

iii) **Sexe :**

- ☐ Garçon
- ☐ Fille

iv) **Votre enfant mange-t-il à la cantine ?**

- ☐ Oui
- ☐ Non

Si oui, précisez la fréquence : …./semaine ou …./mois

v) **Mangez-vous ces légumes chez vous ?**

L'aubergine :

- ☐ Oui
- ☐ Non

Si oui sous quelle(s) forme(s) ? …

La courgette :

- ☐ Oui
- ☐ Non

Si oui sous quelle(s) forme(s) ? …

La betterave :

- ☐ Oui
- ☐ Non

Si oui sous quelle(s) forme(s) ? …

Le poivron:

- ☐ Oui
- ☐ Non

Si oui sous quelle(s) forme(s) ? …

La carotte :

- ☐ Oui
- ☐ Non

Si oui sous quelle(s) forme(s) ? …

La tomate :

- ☐ Oui
- ☐ Non

Si oui sous quelle(s) forme(s) ? …

vi) **Mangez-vous ces fruits chez vous ?**

L'orange :

- ☐ Oui
- ☐ Non

Si oui sous quelle(s) forme(s) ? …

La poire :

- ☐ Oui
- ☐ Non

Si oui sous quelle(s) forme(s) ? …

Le pamplemousse :

- ☐ Oui
- ☐ Non

Si oui sous quelle(s) forme(s) ? …

La pomme :

- ☐ Oui
- ☐ Non

Si oui sous quelle(s) forme(s) ? …

vii) **J'autorise mon enfant à participer à l'expérience sur les rejets alimentaires qui se déroulera dans sa maternelle**

- ☐ Oui
- ☐ Non

Signatures des **deux parents**, le cas échéant :

Questionnaire à destination des parents :

Cochez la case correspondante **:**

	Pas du tout d'accord	Pas d'accord	Ni d'accord ni pas d'accord	D'accord	Tout à fait d'accord
Mon enfant refuse de manger certains aliments à cause de leurs textures	☐	☐	☐	☐	☐
Mon enfant fait le tri dans son assiette	☐	☐	☐	☐	☐
Mon enfant rejette certains aliments après les avoir goûté	☐	☐	☐	☐	☐
Mon enfant peut manger un aliment aujourd'hui et le refuser demain	☐	☐	☐	☐	☐
Mon enfant peut manger certains aliments en grandes quantités et d'autres pas du tout	☐	☐	☐	☐	☐

	Pas du tout d'accord	Pas d'accord	Ni d'accord ni pas d'accord	D'accord	Tout à fait d'accord
Mon enfant recherche constamment des aliments familiers	☐	☐	☐	☐	☐
Mon enfant se méfie des aliments nouveaux	☐	☐	☐	☐	☐
Mon enfant aime seulement la cuisine qu'il connait	☐	☐	☐	☐	☐
Mon enfant rejette un nouvel aliment avant même de l'avoir goûté	☐	☐	☐	☐	☐
Mon enfant est angoissé à la vue d'un nouvel aliment	☐	☐	☐	☐	☐
Mon enfant ne goûte pas un nouvel aliment si cet aliment est en contact avec un autre aliment qu'il n'aime pas	☐	☐	☐	☐	☐

Pour répondre aux questions suivantes imaginez que vous devez décrire un légume ou un fruit à quelqu'un qui ne sait pas ce que c'est. Choisiriez-vous les différents exemples ci-dessous pour décrire ce que sont les fruits et légumes.

(pas du tout d'accord) 1----2----3----4----5----6----7 **(tout à fait d'accord)**

Entourez la réponse:

L'aubergine est un bon exemple de légume	1----2----3----4----5----6----7
La betterave est un bon exemple de légume	1----2----3----4----5----6----7
La carotte est un bon exemple de légume	1----2----3----4----5----6----7
La courgette est un bon exemple de légume	1----2----3----4----5----6----7
Le poivron est un bon exemple de légume	1----2----3----4----5----6----7
La tomate est un bon exemple de légume	1----2----3----4----5----6----7
L'orange est un bon exemple de fruit	1----2----3----4----5----6----7
Le pamplemousse est un bon exemple de fruit	1----2----3----4----5----6----7
La poire est un bon exemple de fruit	1----2----3----4----5----6----7
La pomme est un bon exemple de fruit	1----2----3----4----5----6----7

Merci pour votre participation

Vos réponses sont essentielles pour la suite de notre étude et sachez que les données recueillies sont exclusivement destinées aux travaux du Centre de Recherche et leur confidentialité est garantie.

Pour vous remercier de votre précieuse collaboration, des graines potagères seront offertes à chaque participant.

Appendix 2: Consent form and parental questionnaire (Experiment 3)

Formulaire et autorisation à destination des parents
pour une étude sur les comportements alimentaires de l'enfant (de 2 à 6 ans)

Contact scientifique : Camille Rioux, doctorante en psychologie cognitive
camille.rioux@institutpaulbocuse.com

Merci de bien vouloir nous retourner ce formulaire avant le 16 mars

Questions préliminaires :

i) **Prénom** et **nom** de l'enfant :

ii) **Date de naissance : ……/……/20..**

iii) **Sexe :**

- ☐ Garçon
- ☐ Fille

iv) **Votre enfant mange-t-il à la cantine ?**

- ☐ Oui
- ☐ Non

Si oui, précisez la fréquence en jours : ……../semaine

v) **Mangez-vous ces légumes chez vous ?**

L'avocat :

☐ Oui

☐ Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ? …

La carotte :

☐ Oui

☐ Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ? …

La courge :

☐ Oui

☐ Non

Si oui :

sous quelle(s) forme(s) ?...

à quel(s) moment(s) du repas ? …

La courgette :

☐ Oui

☐ Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ? …

L'haricot vert:

☐ Oui

☐ Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ? …

L'épinard :

☐ Oui

☐ Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ? …

L’oignon :

☐ Oui

☐ Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ?

vi) **Mangez-vous ces fruits chez vous ?**

La banane :

☐ Oui

☐ Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ? …

La fraise :

☐ Oui

☐ Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ? …

L’orange :

☐ Oui

☐ Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ? …

La pomme :

- Oui
- Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ? …

La prune :

- Oui
- Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ? …

Le raisin :

- Oui
- Non

Si oui :

sous quelle(s) forme(s) ? …

à quel(s) moment(s) du repas ? …

vii) **J'autorise mon enfant à participer à l'expérience sur les rejets alimentaires qui se déroulera dans sa maternelle**

- Oui
- Non

Signatures des **parents**, le cas échéant :

Questionnaire à destination des parents :

Cochez la case correspondante :

	Pas du tout d'accord	Pas d'accord	Ni d'accord ni pas d'accord	D'accord	Tout à fait d'accord
Mon enfant refuse de manger certains aliments à cause de leurs textures	☐	☐	☐	☐	☐
Mon enfant fait le tri dans son assiette	☐	☐	☐	☐	☐
Mon enfant rejette certains aliments après les avoir goûté	☐	☐	☐	☐	☐
Mon enfant peut manger un aliment aujourd'hui et le refuser demain	☐	☐	☐	☐	☐
Mon enfant peut manger certains aliments en grandes quantités et d'autres pas du tout	☐	☐	☐	☐	☐

	Pas du tout d'accord	Pas d'accord	Ni d'accord ni pas d'accord	D'accord	Tout à fait d'accord
Mon enfant recherche constamment des aliments familiers	☐	☐	☐	☐	☐
Mon enfant se méfie des aliments nouveaux	☐	☐	☐	☐	☐
Mon enfant aime seulement la cuisine qu'il connait	☐	☐	☐	☐	☐
Mon enfant rejette un nouvel aliment avant même de l'avoir goûté	☐	☐	☐	☐	☐
Mon enfant est angoissé à la vue d'un nouvel aliment	☐	☐	☐	☐	☐
Mon enfant ne goûte pas un nouvel aliment si cet aliment est en contact avec un autre aliment qu'il n'aime pas	☐	☐	☐	☐	☐

Votre enfant aime :

(déteste)	1----2----3----4----5----6----7	**(adore)**

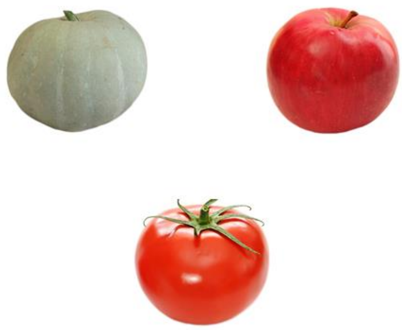
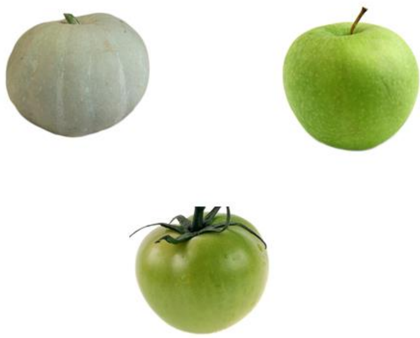
	Entourez la réponse:		**Entourez** la réponse:
L'avocat	1----2----3----4----5----6----7	La banane	1----2----3----4----5----6----7
La carotte	1----2----3----4----5----6----7	La fraise	1----2----3----4----5----6----7
La courge	1----2----3----4----5----6----7	L'orange	1----2----3----4----5----6----7
La courgette	1----2----3----4----5----6----7	La pomme	1----2----3----4----5----6----7
L'épinard	1----2----3----4----5----6----7	La prune	1----2----3----4----5----6----7
L'haricot vert	1----2----3----4----5----6----7	Le raison	1----2----3----4----5----6----7
L'onion	1----2----3----4----5----6----7		

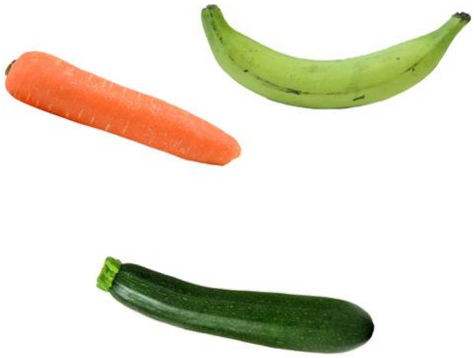
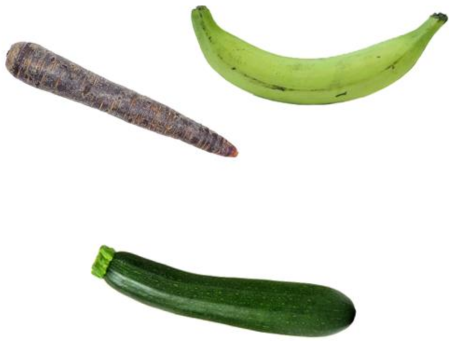
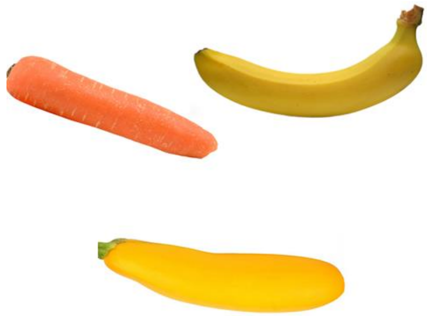
Merci pour votre participation

Vos réponses sont essentielles pour la suite de notre étude et sachez que les données recueillies sont exclusivement destinées aux travaux du Centre de Recherche et leur confidentialité est garantie.

Pour vous remercier de votre précieuse collaboration, des graines potagères seront offertes à chaque participant.

Appendix 3: Complete triad sets of the category-based induction task (Experiment 3)

Target food	**Test picture 2 (fruit similar in color)**	**Test picture 1 (vegetables dissimilar in color)**	**Complete triad set**
Red tomato	Red apple	(a) Orange squash	
		(b)White squash	
Green tomato	Green apple	(a) Orange squash	
		(b)White squash (A)	

Green zucchini	Green banana	(a) Orange carrot	
		(b) Purple carrot	
Yellow zucchini	Yellow banana	(a) Orange carrot	
		(b) Purple carrot	

Appendix 4: Instructions to rate the perceptual similarity of the triad sets (control group, Experiment 3)

Camille Rioux

Doctorante en psychologie cognitive, Institut Paul Bocuse & PSYCLé (Université Aix-Marseille)

camille.rioux@institutpaulbocuse.com

Test de ressemblance visuelle

*Dans ce jeu il faut juger la ressemblance **visuelle** entre deux aliments.*
Par exemple:

banane

chips

Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

1---2---3---4---5---6---7

Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

1---2---3---4---5---6---7

Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

1---2---3---4---5---6---7

Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

1---2---3---4---5---6---7

Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

1---2---3---4---5---6---7

Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

1---2---3---4---5---6---7

Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

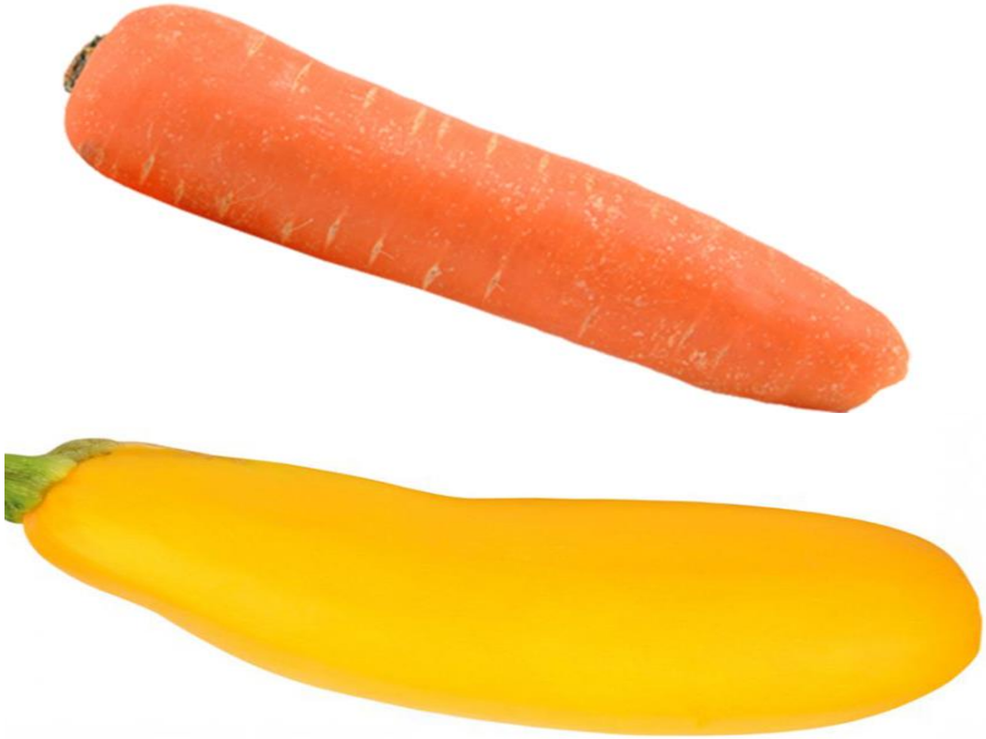
1---2---3---4---5---6---7

Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

1---2---3---4---5---6---7

Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

1---2---3---4---5---6---7



Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

1---2---3---4---5---6---7

Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

1---2---3---4---5---6---7

Sur une échelle de 1 à 7 à quel point ces aliments se ressemblent **visuellement** (entourez la réponse)?

1---2---3---4---5---6---7

Merci pour votre participation

Vos réponses sont essentielles pour la suite de notre étude et sachez que les données recueillies sont exclusivement destinées aux travaux du Centre de Recherche et leur confidentialité est garantie.

Appendix 5: Procedure of the semantic space task (follow-up study to Experiment 3)

Participants were presented with a picture of a shopping trolley consisting of a 8 x 1 grid (see figure below) and several grey iron blocks representing food items (therefore they had to rely on their knowledge about kind rather than perceptual similarity between items as they were all represented by grey blocks).

Note. Compartments marked with an "X" indicate the location were grey blocks could have be placed by a child during a trial, for example two fruits (X_1 and X_2) on the left side of the trolley and one vegetable (X_3) on the other side.

We asked children to help us organize our groceries of fruits and vegetables by placing food items similar in kind close together in the shopping trolley. At the beginning of the task the experimenter provided the child with one triad example. For example the experimenter placed a fruit in the trolley and then another fruit next to him because it was the "same kind of thing". Finally the experimenter placed a vegetable far away from the two fruits because it was "not the same kind of thing". Then for four test triad, the experimenter named three food items (either fruits or vegetables), placed one grey block representing the first food item on one of the grid extremity, and asked children to place the two other blocks (representing the second and third food of the triad). The grid was cleared at the end of each triad.

Appendix 6: Consent form and parental questionnaire (Experiment 4)

VILLE DE LYON

INSTITUT PAUL BOCUSE — École de Management Hôtellerie Restauration & Arts Culinaires — CENTRE DE RECHERCHE

Etude sur les comportements alimentaires de l'enfant (de 2 à 6 ans)
Formulaire et autorisation à destination des parents

Contact scientifique : Camille Rioux, doctorante en psychologie cognitive
camille.rioux@institutpaulbocuse.com

Merci de bien vouloir nous retourner ce formulaire avant le 16 NOVEMBRE

Questions préliminaires :

i) **Prénom** et **nom** de l'enfant :

ii) **Date de naissance : ……../………./20..**

iii) **Sexe :**

- ☐ Garçon
- ☐ Fille

iv) **Votre enfant mange-t-il à la cantine ?**

- ☐ Oui
- ☐ Non

Si oui, précisez la fréquence en jours : ……../semaine

v) **J'autorise mon enfant à participer à l'étude sur les comportements alimentaires qui se déroulera dans sa maternelle**

- ☐ Oui
- ☐ Non

Signatures des **parents**, le cas échéant :

Questionnaire à destination des parents (Cochez la case correspondante) **:**

	Pas du tout d'accord	Pas d'accord	Ni d'accord ni pas d'accord	D'accord	Tout à fait d'accord
Mon enfant refuse de manger certains aliments à cause de leurs textures	☐	☐	☐	☐	☐
Mon enfant fait le tri dans son assiette	☐	☐	☐	☐	☐
Mon enfant rejette certains aliments après les avoir goûté	☐	☐	☐	☐	☐
Mon enfant peut manger un aliment aujourd'hui et le refuser demain	☐	☐	☐	☐	☐
Mon enfant peut manger certains aliments en grandes quantités et d'autres pas du tout	☐	☐	☐	☐	☐

	Pas du tout d’accord	Pas d’accord	Ni d’accord ni pas d’accord	D’accord	Tout à fait d’accord
Mon enfant recherche constamment des aliments familiers	☐	☐	☐	☐	☐
Mon enfant se méfie des aliments nouveaux	☐	☐	☐	☐	☐
Mon enfant aime seulement la cuisine qu’il connait	☐	☐	☐	☐	☐
Mon enfant rejette un nouvel aliment avant même de l’avoir goûté	☐	☐	☐	☐	☐
Mon enfant est angoissé à la vue d’un nouvel aliment	☐	☐	☐	☐	☐
Mon enfant ne goûte pas un nouvel aliment si cet aliment est en contact avec un autre aliment qu'il n'aime pas	☐	☐	☐	☐	☐

Votre enfant aime (**entourez** la réponse):

(déteste) 1----2----3----4----5----6----7 **(adore)**

L'aubergine	1----2----3----4----5----6----7	La betterave	1----2----3----4----5----6----7
La carotte	1----2----3----4----5----6----7	Le chou-fleur	1----2----3----4----5----6----7
La courgette	1----2----3----4----5----6----7	Le maïs	1----2----3----4----5----6----7
Le poivron	1----2----3----4----5----6----7	La tomate	1----2----3----4----5----6----7

A la maison mangez-vous (entourez la réponse) :

1-------------------------------2--3--4--5

Jamais **moins d'une fois par mois** **entre 1 et 3 fois par mois** **une fois par semaine** **plus d'une fois par semaine**

De l'aubergine violette	1----2----3----4----5	De l'aubergine verte	1----2----3----4----5
De l'aubergine blanche	1----2----3----4----5	De la betterave violette	1----2----3----4----5
De la betterave jaune	1----2----3----4----5	De la betterave blanche	1----2----3----4----5
De la carotte orange	1----2----3----4----5	De la carotte blanche	1----2----3----4----5
De la carotte violette	1----2----3----4----5	Du chou-fleur blanc	1----2----3----4----5

Du chou-fleur violet	1----2----3----4----5	De la courgette verte	1----2----3----4----5
De la courgette jaune	1----2----3----4----5	Du mais jaune	1----2----3----4----5
Du mais violet	1----2----3----4----5	Du poivron rouge	1----2----3----4----5
Du poivron vert	1----2----3----4----5	Du poivron jaune	1----2----3----4----5
Du poivron orange	1----2----3----4----5	De la tomate rouge	1----2----3----4----5
De la tomate jaune	1----2----3----4----5	De la tomate verte	1----2----3----4----5

Merci pour votre participation

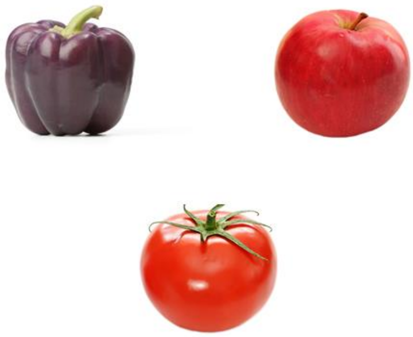
Vos réponses sont essentielles pour la suite de notre étude et sachez que les données recueillies sont exclusivement destinées aux travaux du Centre de Recherche et leur confidentialité est garantie.

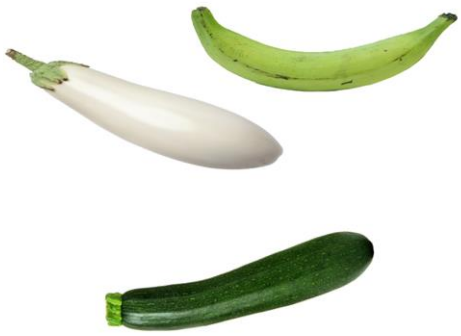
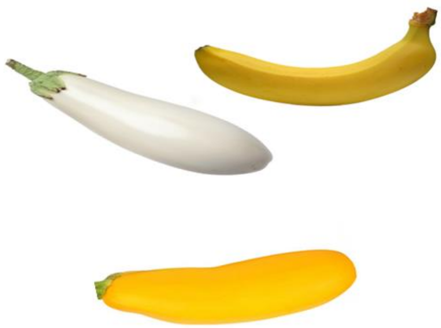
Pour vous remercier de votre précieuse collaboration, des graines potagères seront offertes à chaque participant.

Appendix 7: Food pictures of the categorization task (Experiment 4)

Block 1	Block 2				
Bell pepper (quarter)	**Zucchini (slice)**	**Pear (cube)**	**Eggplant (cube)**	**Tomato (quarter)**	**Citrus fruit (slice)**
Green 	Green 	Yellow 	Dark purple 	Red 	Green 
Red 	Dark green 	Green 	Light purple 	Dark red 	Yellow 
Yellow 	Light green 	Brown 	White 	Yellow 	Pink 
Orange 	Yellow 	Red 	Green 	Green 	Orange 

Appendix 8: Complete triad sets of the category-based induction task (Experiment 4)

Target food	Test picture 1 (fruit similar in color)	Test picture 2 (vegetable dissimilar in color)	Complete triad set
Red tomato	Red apple	(a) Yellow bell pepper	
		(b) Purple bell pepper	
Green tomato	Green apple	(a) Yellow bell pepper	
		(b) Purple bell pepper	

Green zucchini	Green banana	(a) Purple eggplant	
		(b) White eggplant	
Yellow zucchini	Yellow banana	(a) Purple eggplant	
		(b) White eggplant	

Appendix 9: Food of the Willingness to Try Vegetables task (Experiment 4)

Note. From left to right: tomatoes, bell peppers, carrots and zucchinis.

Appendix 10: Thesis' valorisation

Publications in peer-reviewed journals

Rioux, C., Lafraire, J., & Picard, D. (2017). Visual exposure and categorization performance positively influence 3- to 6-year-old children's willingness to taste unfamiliar vegetables. *Appetite, 120*, 32-42. https://doi.org/10.1016/j.appet.2017.08.016

Rioux, C., Lafraire, J., & Picard, D. (2017). Food rejection and the development of food induction in young children. *Journal of Cognitive Psychology*. https://doi.org/10.1080/20445911.2017.1367688

Rioux, C., Lafraire, J., & Picard, D. (2017). 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*, 67-77.

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

Lafraire, J., Rioux, C., Roque, J., Giboreau, A., & Picard, D. (2016). Rapid categorization of food and non-food 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.

Lafraire, J., Rioux, C., Giboreau, A., & Picard, D. (2016). 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

Communications in international conferences with proceedings

Rioux, C., Lafraire, J., & Picard, D. (2016, April). Food categorization's development and food neophobia and pickiness in children from 2-6 years of age. *Proceedings of the 40th Annual Meeting of the British Feeding & Drinking Group (BFDG), Appetite, vol.107, pp.689-690.*

Lafraire, J., Rioux, C., Roque, J., Giboreau, A., & Picard, D. (2015, April). Is it food or not food? How 3–4 years old children respond to a rapid categorization task. *Proceedings of the*

39th Annual Meeting of the British Feeding & Drinking Group (BFDG), Appetite, vol. 101, p. 234.

Lafraire, J., Rioux, C., Giboreau, A., & Picard, D. (2015, April). Food rejections in children: Cognitive and social/environmental factors involved in food neophobia and picky/fussy eating behavior. *Proceedings of the 39th Annual Meeting of the British Feeding & Drinking Group (BFDG), Appetite, vol. 101, p. 234.*

Oral communications in international conferences without proceedings

Rioux, C., Lafraire, J., & Picard, D. (2016, October). Food categorization's development and food neophobia and pickiness in children from 2-6 years of age. *Presentation at the workshop « grandir pour être soi », Sierre, Switzerland.*

Rioux, C., Lafraire, J., & Picard, D. (2016, February). Food rejections of 3-6 years old children: Food categorization and interventions in school canteens. *Presentation at the Institute Paul Bocuse Symposium "Food behaviors in young children: New perspectives", Ecully, France.*

Rioux, C., Lafraire, J., & Picard, D. (2015, September). Validation d'une nouvelle échelle des rejets alimentaires des enfants de 2-6 ans. *Presentation at the 56th Congress of the French Society of Psychology (SFP), Strasbourg, France.*

Rioux, C., Lafraire, J., Giboreau, A., & Picard, D. (2015, July). Young children's food vs non-food categorization abilities during food neophobia peak. *Presentation at the 14th European Congress of Psychology (ECP), Milan, Italy.*

Graphic communications in international conference without proceedings

Rioux, C., Lafraire, J., & Picard, D. (2017, January). The development of food concepts and its relation to food rejections in children from 2 to 6 years of age. *Presentation at the 17th Budapest CEU Conference on Cognitive Development (BCCCD), Budapest, Hungary.*

Rioux, C., Lafraire, J., & Picard, D. (2017, April). Bringing knowledge to the table: the development of food concepts and rejections in young children (2 to 6 years of age).

Presentation at 2017 Society for Research in Child Development Biennial Meeting (SRCD), Austin-Texas, USA.

Rioux, C., Lafraire, J., & Picard, D. (2016, September). « Si je ne connais pas, je ne mange pas ! » Raisonnement inductif et rejets alimentaires chez les jeunes enfants. *Presentation at the 57th Congress of the French Society of Psychology (SFP), Nanterre, France.*