One Bite at a Time

Understanding Picky Eating and Improving Fruit and Vegetable Intake in Young Children



Britt Fleischeuer

Stellingen behorend bij het proefschrift

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Understanding Picky Eating and Improving Fruit and Vegetable Intake in Young Children

1. Picky eating cannot be adequately explained by child-related factors alone (this thesis).
2. Hunger is a simple but effective strategy to increase children's intake of both familiar and unfamiliar fruit (this thesis).
3. Positive reinforcement can make unfamiliar vegetables worth trying before they become worth liking (this thesis).
4. Children's eating behavior is closely linked to that of their caregivers (this thesis).
5. Picky eating is prevalent among young children and is better understood as a continuum than as a categorical phenomenon (this thesis).
6. Demonstrating that an intervention works in research is not the same as successfully implementing it in practice (my field of expertise).
7. We should change children's food environment while also teaching children to make healthier food choices (my field of expertise).
8. Avoidant/Restrictive Food Intake Disorder (ARFID) is an eating disorder characterized by persistent food avoidance or restriction that goes beyond typical picky eating (my field of expertise).
9. Improving children's diets does not always require directly changing what they eat, but changing how they are encouraged to eat it (impact of the results).
10. "You can't force children to love vegetables, but you can make them worth trying" (other).

Britt Fleischeuer
2026

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Britt Sophie Elisabeth Fleischeuer

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Proefschrift

voor het behalen van de graad van Doctor aan de Universiteit Maastricht, onder gezag van de Rector Magnificus, Prof. dr. Jan Smits, overeenkomstig met het besluit van het College van Decanen, te verdedigen in het openbaar op 4 december 2026, om 10:00 uur.

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Chapter 1

General introduction

THE IMPORTANCE OF HEALTHY EATING IN EARLY CHILDHOOD

Healthy eating habits are key determinants for maintaining health and preventing disease across the whole lifespan. A healthy diet includes a diverse consumption of fruits, vegetables, nuts, protein-rich foods, and whole grains, while limiting saturated fats, added sugars, and salt (Brink et al., 2019; Netherlands, 2001). However, unhealthy dietary habits continue to be common worldwide, with only slight improvement observed over the past thirty years. People worldwide consume too little fruit, vegetables, whole grains, nuts, and seafood, and too many sugar-sweetened beverages, red and processed meat, and salt (Miller et al., 2022). In the Netherlands, unhealthy dietary patterns account for roughly 8.1% of the overall disease burden, including cardiovascular diseases, diabetes, chronic diseases, hypertension, and certain types of cancer (RIVM, 2021). While much of the disease burden from an unhealthy diet appears in adulthood as chronic diseases, it is often shaped early in life (Barker, 1997; Fardet & Boirie, 2014). So, healthy eating habits have lifelong consequences. Dietary patterns formed in childhood often persist into adolescence and adulthood, shaping long-term health outcomes (Nicklaus et al., 2005; Ramsay et al., 2017). In the short term, healthy eating plays a crucial role in children's development by providing essential nutrients that promote physical growth, cognitive functioning, and general well-being during a critical period of development (Nyaradi et al., 2013).

Fruit and vegetables are key to a healthy diet. They provide a wide range of nutrients, including dietary fiber, vitamins, and minerals, as well as bioactive compounds like antioxidants (Angelino et al., 2019). These nutrients support normal physiological functions and help protect against the development of chronic diseases (Fulton et al., 2016). Their high fiber and water content also support digestion and help maintain a healthy weight due to the low energy density (Aune et al., 2017; Rolls, 2009). Regular consumption is linked to a lower risk of

non-communicable diseases, including cardiovascular disease and certain cancers, as well as a reduced risk of overall mortality (Boeing et al., 2012).

Nevertheless, both children and adults consume far fewer fruit and vegetables than recommended, in the Netherlands and globally (Leme et al., 2021; Lynch et al., 2014). The recommended daily intake of fruit and vegetables varies by age. For adults, the recommendation is 200 grams of vegetables and 200 grams of fruit per day, yet only 30% and 20% of adults in the Netherlands meet these amounts, respectively (Van Rossum et al., 2023). Among Dutch children aged 0 to 4 years, the recommended intake is 150 grams of fruit and 50 grams of vegetables per day, with 52.4% of the children meeting the fruit recommendation and 68.2% meeting the vegetable recommendation (Statistiek, 2026; Van Rossum et al., 2020). For Dutch children aged 4 to 12 years, 150–200 grams of fruit and 100 grams of vegetables per day are advised, but only 39% meet the fruit guideline, and 46.8% meet the vegetable guideline (Statistiek, 2026; Van Rossum et al., 2020). These data indicate that a substantial proportion of both children and adults in the Netherlands do not reach the recommended intake of fruit and vegetables, and that intake begins to decline from early childhood.

PICKY EATING

One reason for the insufficient fruit and vegetable intake is that children often reject these foods, a behavior known as picky eating (van den Brand et al., 2023). Currently, there is no clear consensus on the exact definition of picky eating. In this thesis, picky eating is defined within the context of fruit and vegetables as a pattern of selective eating in which children eat a limited variety of fruit and vegetables because they reject them, including both familiar and unfamiliar items. This includes refusing fruit and vegetables based

on sensory characteristics (e.g., texture, taste, or appearance) and changes in acceptance over time (Dovey et al., 2008; Rioux et al., 2017). Food neophobia is considered a specific aspect of picky eating, referring specifically to the reluctance to try unfamiliar fruit and vegetables (Rioux et al., 2017; van den Brand et al., 2023).

Picky eating is common in childhood, particularly during early childhood. In this thesis, picky eating is conceptualized as a continuum, meaning that children can vary in the degree to which they display this behavior. At the more severe end of this spectrum lies Avoidant/ Restrictive Food Intake Disorder (ARFID), a clinically significant eating disorder (Zimmerman & Fisher, 2017). However, prevalence studies often conceptualize picky eating dichotomously, classifying children as either picky or non-picky eaters. Reported prevalence rates in early childhood generally range from approximately 6% and 50% (Cardona Cano et al., 2015; Carruth et al., 2004; Chao, 2018; Machado et al., 2016), with estimates varying widely due to differences in definitions, measurement methods, and cultural or geographical context (Taylor et al., 2015).

Picky eating tends to increase around the age of two (Mascola et al., 2010), coinciding with a developmental phase in which children develop more autonomy over feeding and food choices (Cooke et al., 2003; Walton et al., 2017). Although findings differ regarding the presence of a distinct peak (Cardona Cano et al., 2015; Mascola et al., 2010; Taylor et al., 2015), evidence suggests that levels rise from this age and then remain relatively stable over an extended period (Mascola et al., 2010; Nas et al., 2025). While the prevalence of picky eating behaviour tends to decline in later childhood, approximately 8% of children continue to show picky eating behaviour into early adolescence (Cardona Cano et al., 2015; Diamantis et al., 2023; Taylor et al., 2015). Moreover, individual differences in picky eating show moderate to high stability over time, suggesting that relative

differences between children tend to persist despite overall declines (Nas et al., 2025).

Several factors can help explain why fruit and vegetables are often rejected in childhood. When children move away from maternal or formula milk, they need to enlarge their dietary range. However, children are born with limited innate taste preferences and must learn to accept a broader range of foods (Mennella, 2014). From an evolutionary perspective, children have an innate preference for sweetness, which signals ripeness, and an aversion to bitter and sour flavors, which may indicate potential toxins (Birch, 1999). As a result, some fruit and vegetables may be less readily accepted and require repeated exposure and learning before they are consumed regularly. Because children are more likely to eat foods they know and prefer, dietary intake is closely linked to individual food preferences (Brug et al., 2008). Importantly, higher fruit and vegetable consumption in early childhood is associated with healthier dietary patterns later in life (Kemp et al., 2025; Nicklaus et al., 2005). Although picky eating is generally considered a normal part of early childhood development, persistent food rejection during this period may lead to long-term unhealthy dietary habits and a limited range of accepted foods (Mikkilä et al., 2004).

DETERMINANTS OF PICKY EATING

In recent years, scientific interest in picky eating has increased, reflecting a growing recognition of its relevance for child health and development. Existing research suggests that early-life factors are associated with picky eating. For example, a later introduction to lumpy foods (after 9 months) has been associated with higher levels of picky eating, whereas early flavor exposure (through breastmilk or amniotic fluid) is linked to lower levels (Emmett et al., 2018; Nicklaus et al., 2019). In addition, picky eating is, for a substantial proportion,

explained by genetic influences (Cooke et al., 2007; Fildes et al., 2016; Nas et al., 2025; Smith et al., 2017). However, as these genetic influences are not directly modifiable, they offer limited opportunities for intervention beyond reassuring parents that they are not to blame.

Beyond genetic influences, previous research has also identified several child-related characteristics associated with picky eating. These include behavioral and psychological traits such as temperament, personality, and appetitive phenotypes. Research shows that child temperament, particularly negative affectivity, is positively associated with picky eating (Hafstad et al., 2013; Steinsbekk et al., 2020). Furthermore, children who are higher in sensation seeking tend to show lower levels of food neophobia, possibly because they are generally less fearful of new experiences (Maiz et al., 2016). In contrast, higher levels of anxiety are consistently linked to more picky eating and greater food avoidance (Galloway et al., 2003; Maiz & Balluerka, 2018). Additionally, heightened disgust sensitivity and increased sensory sensitivity have been associated with higher levels of picky eating (Egolf et al., 2018; Farrow & Coulthard, 2012; Zickgraf et al., 2022). However, cognitive and/or social factors may also play a role and may include factors that are more malleable.

When deciding whether to accept or reject a food, children engage in different cognitive processes to perceive the multisensory component of the food: how it looks, smells, feels and, tastes. A child needs to remember the sensations and form mental representations of the food. These representations are needed to recognize the food during a new encounter and help to infer how it will taste. Children also need to decide if they want to take the risk to encounter a pleasant or foul taste or play it safe and refuse the food. Importantly, these cognitive processes may help explain why children differ in their responses to similar food items. A better understanding of the cognitive processes underlying picky eating may provide important

insights into why children reject certain foods and how this behavior can be effectively modified.

One cognitive factor that is suggested to be related to picky eating in children is their ability to categorize foods (Rioux et al., 2016). Picky eating in children has been linked to an immature food categorization system in which children with higher levels of food rejection have more difficulty accurately categorizing different foods (Foinant et al., 2022b; Rioux et al., 2018b; Rioux et al., 2016). The reasoning behind this is that categorization helps children organize and interpret the food environment, for example, by distinguishing between fruit, vegetables, and other food types. Without categorization, each object or food item is seen as unique and not generalizable to other members of the same category (Pliner, 2008). For example, a different taste is expected based on incorrect categorization, which does not align with the expectation of the child, making it more likely that the child will not eat it during the next encounter. Also, children with higher levels of picky eating tend to rely more on perceptual features, such as color or shape, whereas children with lower food rejection more often use abstract, category-based inductive reasoning (Rioux et al., 2018a). This reliance on perceptual cues may lead to foods being misclassified and rejected when they only look similar in appearance. For example, a pear might be rejected because it shares the same color as broccoli but is incorrectly categorized as a vegetable when it is, in fact, a fruit. Categorization and induction are also linked to memory (Vlach, 2016), as children need to remember the features of a food to generalize. However, the relationship between induction, memory, and picky eating remains unclear.

In addition, cognitive characteristics associated with autism spectrum disorder (ASD) traits may play a role in picky eating. Higher levels of picky eating are consistently reported in children with ASD (Elsayed et al., 2022; Harris et al., 2023; Postorino et al., 2015). However,

it remains unclear whether similar cognitive mechanisms are also associated with picky eating in typically developing children. Emerging evidence suggests that certain autistic traits in children without an ASD diagnosis may also be linked to picky eating (Foinant et al., 2022a; Zhang et al., 2024). This raises the possibility that cognitive characteristics linked to picky eating in ASD may extend, to a lesser degree, to typically developing children. Such features may include reduced cognitive flexibility, differences in Theory of Mind (ToM), and a heightened focus on specific sensory or perceptual aspects of food. Together, these characteristics may contribute to a more limited range of accepted foods and increased resistance to trying unfamiliar foods.

Finally, children's eating behavior is also shaped by social learning, particularly through observing role models (parents, caregivers, and peers) during shared meals (Suwalska & Bogdański, 2021). Through observational learning, children use others' eating behavior and facial expressions to infer food safety, palatability, and acceptability, which can influence their willingness to try new foods (Birch & Fisher, 1998; Gahagan, 2012). Affective facial expressions are a key source of this social information, as they communicate others' hedonic food experiences. Positive expressions tend to increase children's acceptance of foods, whereas negative expressions reduce it (Barthomeuf et al., 2012; Edwards et al., 2022). However, the effectiveness of such social cues may depend on children's ability to accurately interpret facial expressions and infer taste states. Accordingly, individual differences in emotion and taste recognition may also influence how strongly children are affected by food modelling, potentially contributing to variability in picky eating and fruit and vegetable intake.

Together, these findings suggest that picky eating is partly shaped by how children cognitively and socially process food-related

information. Examining these child-level factors may therefore provide important insight into why some children are more prone to picky eating than others.

While these child-level factors may help explain why children differ in picky eating, it does not give clear guidance on how to make it easier for children to try a fruit or vegetable. Childhood is a key period in which dietary habits are formed, making it a suitable time for interventions that promote fruit and vegetable consumption. In addition, children's eating behavior is also shaped by their environment, including influences from parents and the school (Birch & Marlin, 1982; Costa & Oliveira, 2023; Gregory et al., 2010; Nekitsing et al., 2018). This makes the development of effective and easy-to-implement strategies particularly important, especially those that can be applied within children's everyday environments to increase fruit and vegetable intake. At the same time, picky eating can place considerable strain on this environment, particularly on parents, as repeated food refusal often leads to concern and frustration (Trofholz et al., 2017). Together, this highlights the need for practical and sustainable strategies that support caregivers in promoting children's consumption of fruit and vegetables without being overly demanding in daily life.

To better understand how such strategies may influence eating behavior, it is important to consider the child's underlying motivational processes. Food intake can be shaped by both internal and external factors. Internal factors, such as hunger, can increase a child's willingness to eat. For example, a hungry child may be less selective in order to alleviate discomfort. Studies have shown that hunger reduces the importance of taste and can enhance the rewarding value of food (Ombrato & Phillips, 2021; Siep et al., 2009). Additionally, studies suggest that serving foods at the beginning of meals, when hunger is assumed to be highest, can increase fruit and vegetable consumption in children (Elsbernd et al., 2016; Ferrante et al., 2019;

Gibson & Wardle, 2001; Redden et al., 2015; Spill et al., 2010) However, findings are mixed and often limited by the use of familiar foods and the absence of a clear non-hungry control condition, making it unclear how hunger influences the acceptance of novel foods. Moreover, it remains unclear whether these effects differ for children with higher levels of picky eating.

External factors can also play a role. A well-established strategy to increase children's acceptance of unfamiliar vegetables is repeated exposure, which increases familiarity and reduces food neophobia (Nekitsing et al., 2018). Evidence suggests that at least 8 to 10 tasting opportunities may be needed to increase consumption and liking of an unfamiliar food (Nekitsing et al., 2018). However, despite its effectiveness, exposure alone is often limited in practice, and parents may struggle to apply it consistently (Houston-Price et al., 2019). Therefore, recent research has explored whether adding reinforcement strategies can enhance its effectiveness. Positive reinforcement, which involves providing a reward (e.g., stickers or praise) after a desired behavior, such as tasting a vegetable, has been shown to increase children's vegetable intake by rewarding tasting behavior. In contrast, negative reinforcement involves allowing children to avoid or remove an unpleasant consequence (e.g., not having to do the dishes) after engaging in the desired behavior. Non-food rewards are preferred because they encourage desired eating behaviors without undermining children's intrinsic motivation to like the foods (Cameron et al., 2001; Eisenberger & Cameron, 1996). Positive reinforcement has been shown to increase children's vegetable intake by rewarding tasting behavior (Cooke et al., 2011; Remington et al., 2012; van Belkom et al., 2023), while findings on negative reinforcement are more limited and less consistent (Grieshaber, 1997; Pelchat & Pliner, 1986). Moreover, most studies have focused on familiar or already disliked vegetables, leaving it unclear whether these strategies are also effective for unfamiliar vegetables

that typically elicit stronger neophobic responses. It also remains unclear whether these effects generalize to children with higher levels of picky eating or whether individual differences in reward and punishment sensitivity moderate responsiveness to these strategies.

If these motivational processes can effectively influence the eating behavior of the child, they may represent promising strategies to reduce picky eating.

THIS THESIS

This thesis focuses on children aged 4 to 6 years in elementary school, a developmental period during which a decline in fruit and vegetable intake is commonly observed (Nas et al., 2025).
Picky eating is one of the factors contributing to intake levels that remain well below recommendations. However, there is still limited understanding of the child-related factors that contribute to picky eating, as well as of effective, easy-to-implement strategies to improve dietary habits. Therefore, the overall aim of this thesis is to examine child-related factors associated with picky eating, as well as to identify strategies to increase the consumption and liking of fruit and vegetables among children aged 4–6 years. The studies presented in the following chapters investigate both child-related factors contributing to picky eating (**chapters 2-4**) and behavioral strategies to increase children's consumption and liking of (unfamiliar) fruit and vegetables (**chapters 5-6**).

Child-related (cognitive) factors related to picky eating

Chapter 2 investigates children's inductive reasoning and memory about fruit and vegetables in relation to picky eating. Specifically, it examines how children use perceptual (e.g., color and shape) versus abstract (e.g., food type) features in category-based induction, how well these features are remembered, and how these cognitive processes relate to picky eating.

Chapter 3 examines whether cognitive traits associated with ASD are related to picky eating in typically developing children. Specifically, it investigates the role of cognitive flexibility, ToM, and global–local processing preferences using behavioral tasks, alongside parent-reported measures of ASD traits and picky eating.

Chapter 4 investigates whether individual differences in children's processing of sensory, emotional, and social cues are associated with picky eating and fruit and vegetable intake. Specifically, it examines facial emotion recognition, basic taste identification, recognition of basic tastes through others' facial cues, and social modeling of a food choice, while also accounting for parental influences. Furthermore, relations between child and parent dietary behavior are compared.

Building on the findings of **Chapter 3, chapter 4** further considers the role of social learning processes in relation to picky eating, focusing on social, emotional, and taste-related cues.

Strategies to increase fruit and vegetable intake and liking

Chapter 5 examines whether hunger can be used as a simple strategy to increase fruit intake in young children. Specifically, it examines the effect of hunger on the consumption of a familiar versus an unfamiliar fruit, and explored whether this relationship is moderated by individual differences in picky eating.

Chapter 6 investigates the effectiveness of combining exposure with reinforcement strategies to increase young children's intake and liking of unfamiliar vegetables. Specifically, it compares exposure alone, positive and negative reinforcement using non-food rewards, and a no-intervention control condition. In addition, the potential moderating roles of reward sensitivity, punishment sensitivity, and picky eating are examined.

Chapter 7 provides a general discussion of the main findings of the five studies presented in this thesis. It addresses the theoretical and practical implications of the results, discusses the main limitations, and outlines directions for future research.

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Chapter 2

Food Rejection and The Relation with Category-Based Induction and Memory in Young Children

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ABSTRACT

Background: Childhood rejection of fruit and vegetables (F/V) has been associated with an immature food categorization system, characterized by difficulties in accurately categorizing and making inductions about foods. This may result in variations in the kind of category-based induction children use, such as relying on the color of a fruit/vegetable. Research indicates that children who reject food frequently tend to prioritize perceptual features like color and shape over abstract features, such as the type of food (e.g., tomato) when making food-related inductions. The way children categorize food can also impact what they remember about foods. Food rejection may therefore be related to better memory for perceptual features and diminished memory for abstract features. To explore this further, a pre-registered study was conducted to examine how category-based induction and memory relate to each other, and to children's food rejection. **Methods:** 107 children aged 4-6 years old performed a category-based induction and memory task related to F/V, based on color and shape (perceptual features), and type of food (abstract feature). A vegetable photo task measured vegetable acceptance, and parents completed the Child Food Rejection Scale (CFRS). **Results:** Children generally used color-based induction and displayed better memory for F/V color. Performance on the two tasks was related: higher type-based induction for F/V was linked to better memory for the type of F/V. However, no associations were found with food rejection. **Conclusion:** The category young children use for inductive reasoning about food is related to what they remember best about food. Nevertheless, our study did not establish a relationship between an immature food categorization system and food rejection. Other factors, such as food familiarity, might play a stronger role in children's food acceptance.

Keywords: food rejection; category-based induction; memory; young children; fruit and vegetables; cognitive processes.

INTRODUCTION

Concerns have grown in recent years about the lack of nutritional diversity in children, which is required for optimal growth, survival, and reproduction (Lock et al., 2004; Taylor et al., 2015). The majority of children consume considerably less fruit and vegetables than the recommended five servings per day, which could result in a deficiency of fiber and important micronutrients for proper and healthy child development (Lafraire et al., 2016). This inadequate consumption of fruit and vegetables (F/V) is often attributed to two common types of food rejection, namely food neophobia and picky/fussy eating behavior. The avoidance of unfamiliar foods is known as food neophobia, whereas picky/fussy eating is the rejection of a large variety of foods by children (Dovey et al., 2008; Lafraire et al., 2016). While food neophobia encompasses aspects of picky eating, it is important to note that picky eating encompasses a broader spectrum of selective eating behaviors that go beyond merely rejecting novel foods (van den Brand et al., 2023). Food neophobia and pickiness have been identified as two distinct, though correlated, dimensions of food rejection (Rioux et al., 2017; Rioux et al., 2019). The term 'food rejection' includes both the reluctance to taste new and/or familiar foods and not consuming the foods in meaningful quantities. This behavior tends to be most prevalent between the ages of 2 to 6 years old when children start to reject novel foods and foods they once enjoyed (Addessi et al., 2005; Cooke et al., 2003; Mascola et al., 2010). According to Cardona Cano et al. (2015), the prevalence of food rejection in 3-year-old children in the Netherlands was found to be 27.6%. This prevalence rate of 27.6% was determined using two eating-related measures from the 'Child Behavior Checklist' (CBCL). Mothers rated their child's eating behavior based on 'does not eat

well' and 'refuses to eat' on a 3-point Likert scale. Scores of 4 or higher on these questions, which ranged from 2 to 6, were indicative of food rejection, encompassing children perceived as demonstrating food rejection sometimes or often. Although most children outgrow this food rejection phase, individual differences persist into adulthood, demonstrating that young children who eat more fruit and vegetables continue eating healthier as they age (Nicklaus et al., 2005). In the long run, food rejection of fruit and vegetables may increase the risk of chronic diseases such as obesity, cardiovascular diseases, and certain types of cancer (Chamoun et al., 2018; Fardet & Boirie, 2014).

An innovative new line of studies suggested that food rejection in young children is a behavioral consequence of an immature food categorization system (Rioux et al., 2016). Categorization is a fundamental cognitive process that entails comparing an item to various exemplars to establish meaningful connections. It enables us to group similar objects or foods together based on shared characteristics (Murphy, 2004). Without the ability to categorize, each individual object or food item would be perceived as unique, and its attributes could not be generalized to other members of the same category (Pliner, 2008). Building on the concept of an immature food categorization system, research supports the idea that highly picky and neophobic children exhibit poorer categorization performances than those with lower picky and neophobic eating tendencies (Foinant et al., 2022b; Rioux, Lafraire, et al., 2018b; Rioux et al., 2016). The studies by Rioux, Lafraire, et al. (2018b); Rioux et al. (2016) have shown that preschool children who were better at distinguishing fruit and vegetables displayed a greater willingness to consume unfamiliar vegetables and rejected fewer foods. For example, a pear might be rejected because it shares the same color as broccoli but is incorrectly categorized as a vegetable when it is, in fact, a fruit. This emphasizes the significance of children's categorization abilities in shaping their food acceptance patterns.

Further research has indicated that children with higher food rejection tendencies tend to focus on perceptual features (e.g., color or shape) to generalize knowledge, using perceptual-based induction. On the contrary, children showing less food rejection tend to focus more on abstract features to generalize knowledge, using type-based (e.g., different appearances of a bell pepper) or taxonomic induction (e.g., different types of fruits) (Rioux, Lafraire, et al., 2018a). This suggests that a highly neophobic and picky child may decline to try a yellow bell pepper at school, perceiving it as distinct from the familiar red bell pepper served at home, due to their use of color-based induction to infer it is not a bell pepper. Thus, highly picky and neophobic children might rely more on perceptual similarity rather than type membership to decide to eat it, unlike children with low levels of food rejection when making inductions in such situations (Pickard et al., 2023).

The aforementioned studies (Foinant et al., 2022b; Rioux, Lafraire, et al., 2018a, 2018b; Rioux et al., 2016) found a relation between categorization/category-based induction and food rejection, although there are also some inconsistent findings. For instance, the study by Rioux, Lafraire, et al. (2018b) incorporated an induction task, asking children to match a target food picture with two test food pictures. Children could make either a taxonomy-consistent response (e.g., both are fruits) or a perceptual-consistent response (same color), as they needed to generalize one property of the target food to one of the test foods. The expected relation between willingness to try atypically colored vegetables and the use of taxonomy-based induction was, however, not found. Furthermore, a recent study conducted by Pickard et al. (2023) investigated the relationship between food rejection in preschool children and two types of category-based induction: script induction (e.g., both foods are dinner foods) and thematic association (e.g., expecting a sandwich at lunch). Interestingly, their findings showed a negative relationship between food rejection and

category-based induction in the food domain in one of their studies but not in the other. In sum, there are indeed indications that food rejection is related to lower performance on food categorization tasks and less mature category-based induction, although not all results are consistent.

The process of how children categorize and induce stimuli can also influence the aspects they remember most vividly, and conversely, what they remember can also influence their categorization and induction skills. For example, when children engage in the process of induction, they tend to enhance their attention and recall of specific features, such as the color, shape, or type of food, more effectively. When referring to the 'type of food,' we are specifically considering the same type of food with different appearances, such as a cucumber, which can be presented as either whole or cut. This interaction between induction and memory has been studied by Vlach (2016). In this study, children aged two to four performed a memory task related to the shape, color, and size of objects and an induction task about the same features. It was expected that the development of a shape bias (i.e., when using induction) would have effects beyond in-the-moment attention, classification, and generalization. A correlation between learners' categorical bias (e.g., shape bias) and their recall of object perceptual properties was hypothesized. Specifically, the emergence of a shape bias was believed to be linked to the formation of a memory bias for shape information. It was found that children who use induction more often based on shape also had a better memory for the shape of objects. Likewise, children who used more induction based on color and size had a better memory for these features (Vlach, 2016). These results highlight the relationship between category-based induction and memory in children. As they engage in the practice of induction, their attention to certain attributes might become heightened, leading to improved memory encoding and retrieval for those features

(Samuelson & Bloom, 2008; Vlach et al., 2014).

Relating this to the food domain, a child might focus on the color of a fruit/vegetable to induce some knowledge and remember that a red food (i.e., color) had a particular taste, and not that a bell pepper (i.e., type) had this taste. This might influence their response when encountering a different red food or a yellow bell pepper. Their recognition might be less effective, and their expectation might more often be incorrect, which could lead to dislike of the wrongly identified foods and eventually more food rejection. So, children who rely on perceptual cues during induction and may have a better memory of these cues may demonstrate more food rejection. Yet, a possible relationship between induction and memory for food and the connection with food rejection in children has not been studied. If children's food rejection is indeed influenced by the type of induction used and memory of specific features of foods, this could be used to develop interventions to stimulate healthy eating behaviors in children (e.g., by learning that the type of an F/V says more about taste than the color or shape).

The present study aimed to examine category-based induction (including color, shape, and type-based induction) and memory in children showing diverse levels of food rejection. In addition, it is examined whether there is a relationship between category-based induction and memory performance. In this study, perceptual features of F/V (i.e., color and shape) are compared to a more abstract feature, namely the type of F/V (e.g., considering the same type of food, for example, a cucumber, with different appearances, such as whole and cut). It is hypothesized that (1) children who demonstrate more food rejection show more perceptual-based induction based on the color and shape, and less on the type of F/V. (2) Children who demonstrate more food rejection have a better memory for the color and shape of F/V, and less for the type of F/V. (3) The ability

to use type-based induction is significantly related to the children's memory performance for the type of F/V.

METHODS

Ethical approval

The Ethical Committee of the Faculty of Psychology and Neuroscience of Maastricht University approved the present study (ERCPN-OZL-233-11-02-2021_S8). Before the start of the study, parents gave written consent for their child's participation. The choice of the child was also respected if they did not want to participate at the time of testing. The study was pre-registered on AsPredicted (125931) (https://aspredicted.org/see_o4ne.php), and analyses have been performed as registered.

Participants

A sample size calculation was performed using G*Power 3.1.9.6 version to estimate the number of participants required for the study, focusing on the analysis that needed the most power (Faul et al., 2007). Performing a linear multiple regression analysis (fixed model, R^2 increase) with an effect size of 0.15, alpha of 0.05, and a power of 0.90, 73 participants were required. Due to the possibility of outliers, incorrect measurements, or smaller effects, we aimed to recruit up to 100 participants. Due to assessing whole classes at schools, 115 parents agreed for their children to participate in the study. The children were pupils at primary schools in the south of the Netherlands and were primarily Europeans from various social classes. Several schools were contacted, and schools that wanted to participate were selected. Two children were ill at the time of testing, one did not want to participate, and one parent who granted informed consent did not include the questionnaire. Additionally, 4 participants were later excluded from the analysis due to distraction during the tasks. This left a final sample of 107 children, comprising

59 boys and 48 girls aged between 4 and 6.7 years old (*M* = 5.01, *SD* = 0.63).

Procedure

Children were tested one by one in a quiet spot at their school. All children started with 3 practice trials of the feature memory task, with non-food items. Afterward, participants were presented with three tasks: a feature memory task, a category-based induction test, and a vegetable photo task. The order of the feature memory task and category-based induction test was randomized across participants to prevent order effects. To prevent any interference with the performance of the feature memory task and category-based induction test, the vegetable photo task was consistently conducted last. In the end, the children received a 'vegetable diploma' and could return to their class. The average duration of the tasks was 15 minutes per child.

Measurements

Demographic variables

Several demographic variables (age (in years), gender (boy or girl), and relation to the child) were collected through a parental questionnaire.

Child Food Rejection Scale

Food rejection was assessed by parents using the Child Food Rejection Scale (CFRS) (Rioux et al., 2017). The CFRS contains two subscales that correspond to two aspects of food rejection: food neophobia (6 items) and pickiness (5 items). Caregivers were asked how much they agreed with the statements regarding their child's neophobia (e.g., "My child only likes familiar foods") and pickiness (e.g., "My child sorts his/her food on the plate"). Each item was scored by one of the parents on a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly

agree). The total score could range from 11 to 55, with higher scores indicating greater food neophobia and pickiness. More specifically, scores for neophobia could range from 6 to 30 and from 5 to 25 for pickiness.

Category-based Induction Test

The category-based induction test, adapted from Vlach (2016), was designed to assess children's inductions related to various fruit and vegetables. Adaptations included the substitution of foods for objects, the replacement of the size feature with the type of food feature, and the exclusion of additional delays, focusing solely on immediate measurements. In the study by Vlach (2016), the task is referred to as measuring a 'categorical bias'. However, it is important to note that the underlying principle of the task is inductive reasoning. To enhance clarity and emphasize that we are measuring the same cognitive ability, we have decided to refer to the task as 'category-based induction'. The kinds of inductions possible in the current study were color-, shape-, or type-based. By 'type,' we refer to the same kind of fruit or vegetable but with varying appearances, including both whole and cut into pieces. During the category-based induction test, children were presented with nine trials of a single fruit or vegetable, each followed by a new linguistic label (e.g., "This contains Rika"). Three test stimuli were then provided below the target stimuli: one with the same color as the target, one with the same shape, and one with the same type. The child's task was to infer which of the three F/V options matched the target (e.g., "Which of these three do you think also contains Rika?"). The trial answers were counterbalanced, and the trials were shown in random order. The type-based induction score was calculated as a percentage by dividing the number of times children chose type-based induction of F/V by the total number (9, but in 15 cases, due to software failure, only 8 trials were offered). Higher percentages indicated a preference for type-based induction, while lower scores suggested a tendency for

perceptual-based inductions, involving color or shape. Examples are shown in Figure 1, and the complete list of stimuli can be found in the supplementary material.

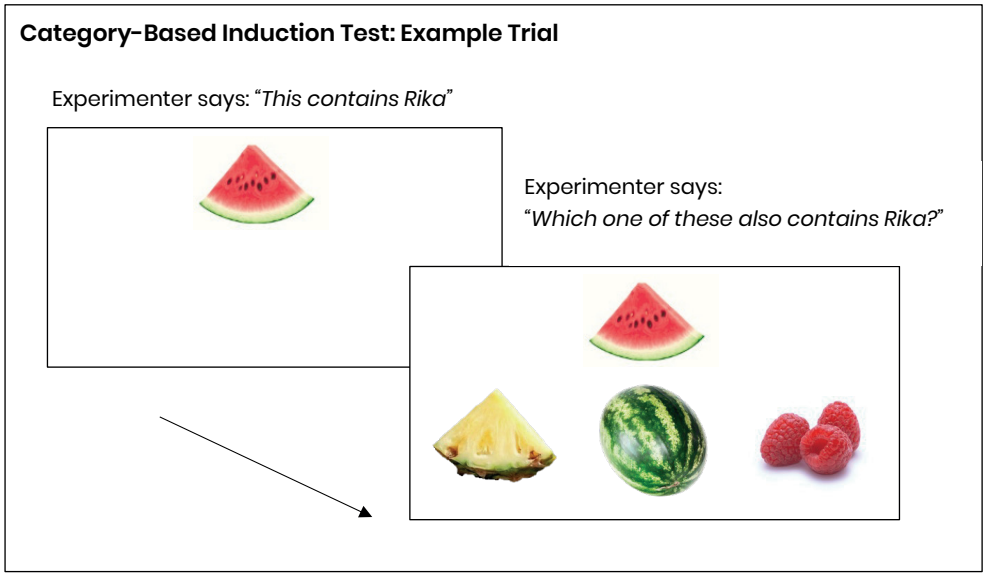


Figure 1. Example of the stimuli used in the Category-Based Induction Test. The ordering of the different types of induction types possible was counterbalanced across trials.

Feature Memory Task

The feature memory task, adapted from Vlach (2016), aimed to assess children's ability to recall three different F/V features: color, shape, and type (same kind of F/V with different appearances). These adaptations, derived from the task by Vlach (2016), include substituting foods for objects, replacing the size feature with the type of food feature, increasing the number of trials from 9 to 24, and excluding additional delays, with measurements taken immediately. First, a target F/V was shown for four seconds ("Look at this fruit/vegetable") after which the target F/V disappeared, and three test pictures of the F/V appeared. The child had to identify the test F/V that most resembled the target ("Which one is most similar to the F/V you have seen before"). Every trial had only one feature matching the target picture, either color, shape, or type, while the other features remained the same. For example, in the color memory trials, all the test objects had the same shape and belonged to the same type (e.g., cauliflower), but only one was the same color as the target F/V. Thus, in this case, correct answers depended on remembering the color of the target F/V. The order of the correct answer was counterbalanced across trials. The task contained 24 trials in total (8 per feature), which were displayed in random order. The score per feature was defined by the number of correct remembered answers that the child indicated. The score could range from 0 to 8 for each feature. Examples are shown in Figure 2 and the complete list of stimuli can be found in the supplementary material.

The feature memory practice test consisted of 3 trials involving non-food items. In each trial, a target object (e.g., Micky Mouse, a pink dress, and a Cars car) was presented. Subsequently, three test pictures were shown, with one of them being the correct answer. The correct answer was determined based on a match with the target picture in terms of either the shape, color, or type of the object. Incorrect trials were repeated until the children succeeded.

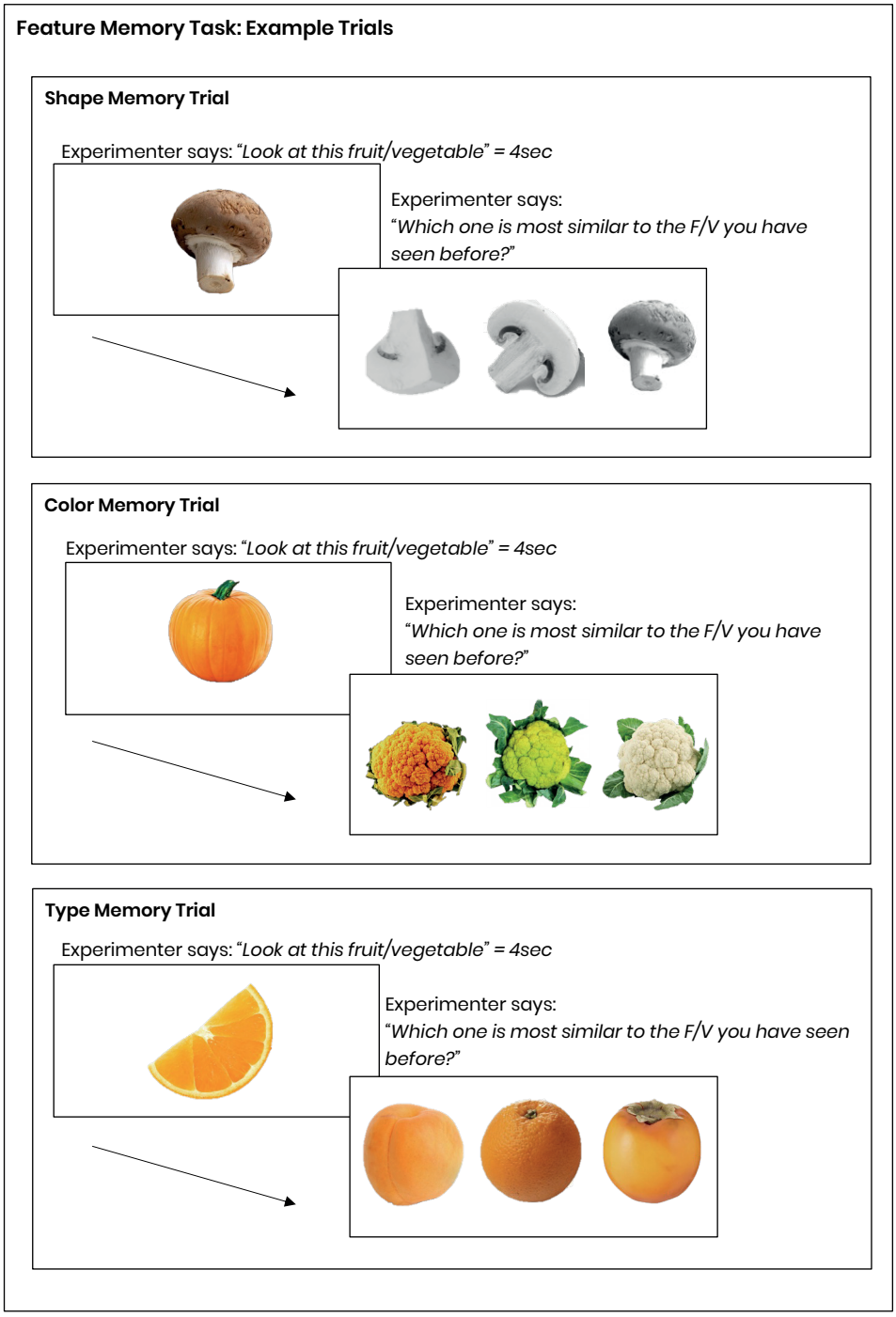


Figure 2. Examples of the stimuli used in the Feature Memory Task. The ordering of the correct answer was counterbalanced across trials.

Vegetable Photo Task

The Vegetable Photo Task (VPT) (Pliner, 1994) was aimed at assessing children's knowledge about and willingness to try vegetables. This included 6 familiar (tomato, carrot, bell pepper, cucumber, mushroom, broccoli) and 6 unfamiliar (fennel, celeriac, okra, lotus root, romanesco, artichoke) vegetables (Ocké et al., 2008). One by one, children were shown a picture of a familiar or unfamiliar vegetable with three corresponding questions: (1) "Do you know this vegetable?" (2) "Have you ever tasted this vegetable?" and (3) "Would you like to taste this vegetable?" The first two answers could be answered with "Yes", "No", or "I don't know", with higher scores indicating more vegetable knowledge. The last question (willingness to try) is answered using a 4-point Likert scale (0 = strongly disagree, 1 = disagree, 2 = agree, 3 = strongly agree), which was replaced with smileys for the children to make understanding easier. We ensured children understood the scale's meaning by explaining each smiley: "If you would really like to taste it you may point to this smiley face (the experimenter points to the most green smiley face), if you don't want to taste something at all you may point to this smiley face (the experimenter points to the sad red smiley face), if you would like to taste something a little bit you may point to this smiley face (the experimenter points to the light green smiley face), and if you would like to taste something rather not, you may point to this face (the experimenter points to the light orange sad smiley face)." Following this, we assessed the child's comprehension by asking: 'What do you really like to eat (e.g., French fries)? Can you show me which smiley face it belongs to, if you could taste it? (Mourmans et al., 2023). The scores for willingness to try (WTT) could range from 0 to 36, with higher scores indicating a greater willingness to try both familiar and unfamiliar vegetables, implying less pickiness and neophobia.

Data analysis

Primary analyses

The data were collected with Qualtrics on an iPad and analyzed with IBM SPSS (version 27.0, SPSS Inc, Chicago, IL). The data was first screened for outliers. Influential outliers were Winsorized, which replaced the extreme values with the maximum and minimum values at the threshold. In total, 11 out of 428 data points were identified as outliers in one of the variables of the category-based induction test or feature memory task, which were subsequently Winsorized. To clarify, in the feature memory task, we identified outliers as 6 participants whose scores fell 2.5 times the standard deviation below the mean, signifying a high frequency of errors. In the category-based induction test, outliers were defined as 3 participants who achieved scores 2.5 times the standard deviation above the mean, indicating an exceptionally high reliance on shape-based induction. Additionally, 3 participants were identified as outliers in the category-based induction test for scoring 2.5 times the standard deviation above the mean, suggestive of a strong preference for type-based induction. Participants were removed from further analysis if the experimenter discovered during testing that the child was unable to complete the test properly (did not understand the task or lack of concentration). This happened with four children. Descriptive statistics of all tasks were analyzed, and assumptions were checked. Control variables were gender and age in all analyses.

First, to test the relation between category-based induction and food rejection a multiple linear regression analysis was performed. It was expected that children who demonstrate more food rejection would use more category-based induction based on the color and shape of F/V, and less on the type of F/V. The CFRS functioned as the independent variable, predicting the type-based induction score. Second, to test the relation between memory and food rejection, an ANCOVA for repeated measures was performed. It was expected that

children who demonstrate more food rejection, would have a better memory for the color and shape of F/V, and less for the type of F/V. The scores on the three types of feature memory tasks functioned as the within-subject factor. The CFRS score was considered as the covariate. Post-hoc analyses, including pairwise comparisons, were carried out using a Bonferroni correction. Third, to test a relation between category-based induction and memory performance, an ANCOVA for repeated measure was performed. The within-subject factor was the three feature memory scores (color, shape, and type), and the covariate was the type-based induction score.

Secondary analyses

Moreover, a correlational analysis between the CFRS and the willingness to try (WTT from the VPT) was performed to check if the child's self-report corresponds to parental responses regarding food rejection. Last, the primary analyses were also performed with the WTT measure instead of the Child Food Rejection Scale (CFRS) to explore whether utilizing a child measure rather than a parental measure would yield significant results (corrected for multiple testing using a Bonferroni correction).

RESULTS

Relationship between category-based induction and food rejection

The results of the category-based induction scores and food rejection scores are presented in Table 1. It was expected that children who demonstrate more food rejection would show more category-based induction based on the color and shape of F/V, and less on the type of F/V. This was examined using a regression analysis in which the CFRS functioned as the independent variable predicting the type-based induction score, controlling for age and gender. The model explained 3% of the variation in the type-based induction score and demonstrated that gender (β = -0.7, t = -0.67, p = .50), age (β = 0.10, t = 1.02, p = .31), and CFRS (β = -0.12, t = -1.23, p = .22) were not significantly related to the type-based induction score of F/V. The results did not provide evidence supporting a relationship between food rejection and category-based induction. In general, children primarily used color-based induction (M = 0.52, SD = 0.25), followed by type-based induction (M = 0.27, SD = 0.16), and shape-based induction (M = 0.20, SD = 0.18). Using paired sample t-tests including a Bonferroni correction, all induction scores differed significantly from each other: shape – color (t(106) = -8.21, p = < .001), shape – type (t(106) = -3.24, p = .006), color - type (t(106) = 6.85, p = < .001).

Table 1.

Outcome tasks and parental questionnaire

Variables	N	Minimum	Maximum	Mean	Std. deviation
Induction Shape (%)	107	0	0.64	0.20	0.18
Induction Color (%)	107	0	1	0.52	0.25
Induction Type (%)	107	0	0.66	0.27	0.16
Memory Shape	107	4.01	8	6.74	1.05
Memory Color	107	4.59	8	7.11	0.99
Memory Type	107	2.19	8	5.45	1.27
CFRS	107	12	51	31.05	7.54
WTT	107	0	36	18.49	7.43

Note. CFRS: Child Food Rejection Scale; WTT: Willingness to Try; from the Vegetable Photo Task.

Relationship between memory and food rejection

The results of the memory and food rejection scores are presented in Table 1. It was expected that children who demonstrate more food rejection would have a better memory for the color and shape of fruit and vegetables, and less for the type of fruit and vegetables. This was examined using an ANCOVA for repeated measures with the different memory scores as the within-subject factor and the CFRS as the covariate. Prior to the analysis, the covariate was centered (M = 31.05, SD = 7.54). Adopting Greenhouse-Geisser, a main effect for the within-subject factor 'memory feature' was found (F(1.89, 198.63) = 78.73, p = < .001) and no interaction with food rejection was observed (F(1.89, 198.63) = 1.48, p = .23). Moreover, no main effect was found for food rejection (F(1, 105) = 0.02, p = .89). Thus, the results did not indicate that food rejection is related to memory performance. Children, on average, displayed the best memory for the color of F/V (M = 7.11, SD = 0.99), followed by shape (M = 6.74, SD = 1.05) and type (M = 5.45, SD = 1.27). Using pairwise comparisons including a Bonferroni correction, all memory scores differed significantly from each other: shape – color (p = .02); shape – type (p = .003); color – type (p = .003). Furthermore, gender had a significant relation with the memory scores (F(1, 104) = 4.95, p = .03). Overall, girls performed significantly better than boys in the memory task (M girls = 19.82, SD = 2.08 vs M boys = 18.97, SD = 2.25). No effect of age was found (F(25, 80) = 1.60, p = .06).

Relationship between memory and category-based induction

It was expected that children's type-based induction of F/V would be significantly related to their memory performance for the type of F/V. This was examined using an ANCOVA for repeated measures with the different memory scores (shape, color, and type) as the within-subject factor and the type-based induction score as a covariate. Before the analysis, the covariate was centered (M = 0.27, SD = 0.16). Moreover, a Greenhouse-Geisser correction was used adjusting for a lack of sphericity in the repeated measures ANCOVA. This correction

serves a dual purpose: it estimates epsilon (a measure of sphericity) and consequently adjusts for the lack of sphericity. Adopting Greenhouse-Geisser, a main effect of the within-subject factor 'memory feature' was found ($F(1.93, 202.27) = 80.85$, $p = < .001$). There was no significant main effect of the type-based induction score ($F(1, 105) = 0.61$, $p = .44$), however, a significant interaction (memory feature x type-based induction score) was observed ($F(1.93, 202.27) = 4.38$, $p = .02$). Simple effects (Figure 3) showed that a stronger type-based induction was associated with better memory for the type of fruit and vegetables ($F(1, 105) = 4.30$, $p = .04$). Again, gender had a significant relation with the memory scores ($F(1, 104) = 5.19$, $p = .03$) and no effect of age was found ($F(25, 80) = 2.22$, $p = .08$).

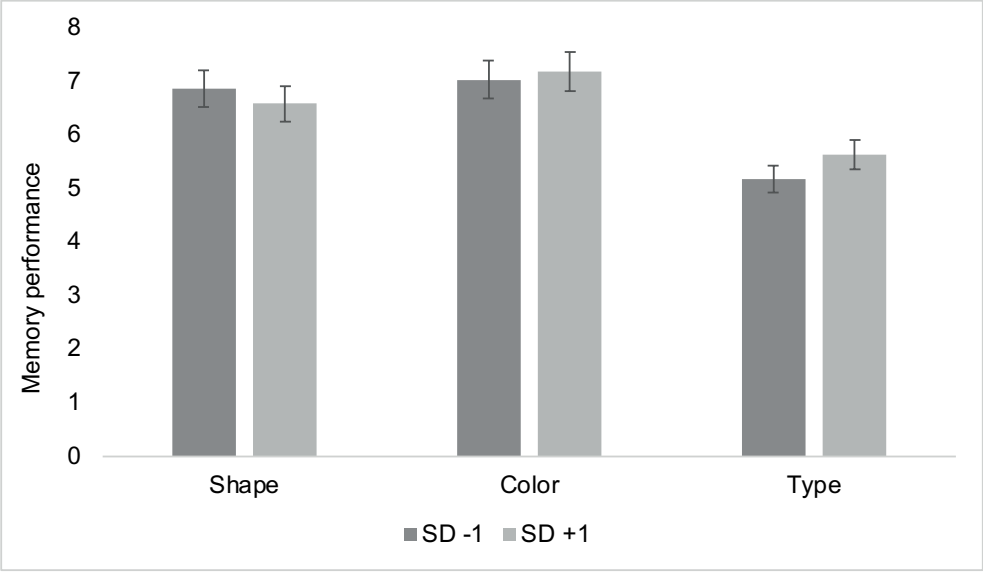


Figure 3. Simple effects of type-based induction scores (estimated with -1 SD and +1 SD) on memory performance. Error bars represent 95% confidence intervals

Secondary analyses

To assess the similarities between the parental questionnaire and child-based task measuring food rejection, a correlation analysis between the CFRS and the willingness to try from the VPT was performed. The two measures were found to be negatively correlated (r = -0.23, p = .016), meaning that children who indicated that they were less willing to try familiar and unfamiliar vegetables scored higher on the parental food rejection scale. When using the WTT instead of the CFRS as a measure for food rejection, the same pattern of results is found as in the other primary analyses, meaning that food rejection was not related to category-based induction or memory performance.

DISCUSSION

The present study examined the relation between category-based induction and memory, and how it relates to children's food rejection of fruit and vegetables. The results showed that (1) Children's category-based induction predominantly relied on color, followed by type and shape, respectively, yet this preference for induction did not correlate with their level of food rejection, (2) Overall, children displayed the best memory for the color of fruit and vegetables, followed by shape and type, but memory performance was not associated with food rejection, and (3) Children who used type-based induction more often, also had a better memory for the type of F/V. So, the findings from the current study appear to illustrate a noticeable color bias in the food domain for children 4-6 years of age.

Category-based induction unrelated to food rejection

Independent of their level of food rejection, children mainly used color to make inductions about different fruit and vegetables. This was also found by Macario (1991), who showed that children typically categorize novel food items using color rather than shape. Furthermore, in the context of generalizing novel words and features to food as opposed to objects, children between the ages of 2 and 3 also appear to prioritize information related to color and texture over shape (Lavin & Hall, 2001). Rioux et al. (2016) further highlighted the significance of color in the categorization of F/V. Their study revealed that typically colored vegetables were notably more accurately categorized compared to atypically colored ones.

The studies by Foinant et al. (2022b); Rioux, Lafraire, et al. (2018b); Rioux et al. (2016) showed that children who were better at distinguishing fruit and vegetables displayed less food rejection. However, the study by Foinant et al. (2022b) only found a significant relation between categorization (i.e., of foods and non-foods) and food neophobia, but not food pickiness. Furthermore, a measure related to induction (i.e., taxonomy-consistent response or perceptual-consistent response), which closely resembles the induction task used in the present study, did not show a significant relationship with food rejection in one study (Rioux et al, 2018b), but it did in another (Rioux et al, 2018a). Additionally, the study by Rioux, Leglaye, et al. (2018) also examined the relationship between inductive reasoning and food rejection in preschoolers regarding food and artifacts and only partly confirmed that food neophobia, and not food pickiness, relates to reduced inductive reasoning abilities. However, it is essential to note that our study introduced a novel element by examining type-based induction (i.e., the same food with different appearances). Unlike the mentioned studies that focused on differentiating between fruit and vegetables or distinguishing foods from non-foods, our investigation delved into a different aspect of categorization, which

may account for the absence of the expected effect. Notably, the inductive reasoning task by Rioux, Lafraire, et al. (2018a) explored two inductive reasoning possibilities (color and category), while our study introduced three options (color, shape, and type). It is possible that food rejection is more closely associated with induction based on category membership (i.e., fruit or vegetable) rather than type membership, which pertains to the same type of food. Moreover, the study by Rioux, Lafraire, et al. (2018a) also demonstrated that children with higher levels of food rejection tended to rely more on color cues rather than label cues, but included the use of auditory input, which increased the performance of the children, probably because it made color less salient. The present study solely used visual cues, which might also explain the different findings.

Other studies examined food rejection and its relationship with other types of category-based induction, such as thematic (e.g., bread and butter) and taxonomic (e.g., bread and pasta) categorization. Again, results were inconsistent, with some studies showing a relation (Pickard et al., 2021) and others partly (Pickard et al., 2023). Again, our study concentrated on type-based induction rather than thematic or taxonomic induction, providing a potential explanation for the differences in outcomes.

Interestingly, picky eaters have also been found to have difficulties in non-food induction tasks (Fisher et al., 2015; Lafraire et al., 2020). This finding suggests that a possible immature categorization is not specific to the food domain. This casts doubts about a possible causal relationship between induction and food rejection. A third variable (such as socioeconomic status, general developmental level, or experience with food) might also explain the observed relationships. Taken together, the findings on the relation between category-based induction and food rejection are not robust and might depend on the specific way the stimuli are presented (e.g.,

with the use of auditory input). This suggests that the causal role of category-based induction in food rejection might be limited.

Memory performance unrelated to food rejection

According to this study, regardless of food rejection, children show superior memory for the colors of various fruit and vegetables by the ages of 4 to 6. This finding aligns with children's preference to predominantly categorize F/V based on color (Macario, 1991). It suggests that children tend to allocate greater attention or meaning to the color aspect of fruit and vegetables, leading to enhanced memory retention compared to their recollection of the shape or type of food. As children continue to develop, their memory for the type of F/V may improve, as it aids in generalization (e.g., recognizing slices and a whole carrot both as a carrot) and is more relevant for the selection of food. This can potentially overshadow their memory for color, which gradually decreases in importance. The study by Vlach (2016) showed that 2- to 4-year-old children had the best memory for the shape of different objects, not color. However, it is unsurprising that this aspect was not observed in the present study, as the shape of F/V holds lesser significance compared to their color (Macario, 1991), which is different when identifying objects used in the study by Vlach (2016). Moreover, Vlach (2016) employed the feature 'size' instead of 'type' and incorporated response measurements following specific time delays. This could explain the difference in findings between the current study and the study by Vlach (2016)

Memory for perceptual features of F/V was not related to children's food rejection, nor was a relation between their general memory performance and food rejection found. The study by Foinant et al. (2022a) examined the association between executive functions and young children's food rejection, focusing on working memory as one aspect. To assess working memory, a sorting task was designed where children had to sort stimuli mentally that were visually and

auditorily presented at first. In accordance with the present study, no significant associations were found between working memory performance and children's tendency to reject certain foods. It seems, therefore, that neither a better general memory nor a memory for specific features of fruit and vegetables is of great importance to food acceptance.

A gender difference showed that girls performed significantly better on the memory task, irrespective of specific features. It has been frequently observed that girls tend to have a (slightly) better memory than boys (Gur et al., 2012; Heisz et al., 2013).

Type-based induction and memory for type are related to each other

The present study shows a relationship between type-based induction and children's memory for the type of different F/V. This result suggests a relationship between the way children induce features of F/V and how they remember them. As children learn to categorize and generalize fruit and vegetables in a specific manner, they may develop a tendency to prioritize relevant categorical features in memory. If children perceive a particular perceptual feature as crucial for categorization, they may encode this information more deeply, ensuring its accessibility from memory over time. This proposed pathway was also supported by the study of Vlach (2016).

Parental and child measures of food rejection are related

The parental assessment of their child's food rejection was significantly related to the child's self-reported willingness to eat F/V. While the correlation between the two measures was not particularly strong, it is worth noting that the parental questionnaire encompassed general eating behavior, whereas the child's measurement specifically targeted F/V. Future studies aimed at the intake of fruit and vegetables could enhance the parental measurement by

explicitly instructing parents to assess food rejection related to F/V. The correlations show that children at this young age can report their food preferences reliably.

Limitations and future research

Although this study suggests that food rejection is not or not very strongly related to category-based induction and memory of F/V, the study used an artificial setting on an iPad and did not use real food for assessing willingness to try vegetables. Moreover, the type of food might be more relevant in real life when selecting foods to eat. The present study used as an abstract feature the 'type of F/V', which was operationalized by depicting parts of the whole (e.g., a piece of bell pepper belongs to the whole bell pepper). Other studies that did find a relationship with food rejection used a different abstract categorization, like taxonomy (Rioux, Lafraire, et al., 2018a). However, the use of type as an abstract feature seemed appropriate for the children's age, and they exhibited significant variance in inference-making and food rejection scores. Yet, it might be the case that 'type' has a less salient relation with food rejection in comparison to 'taxonomy. Furthermore, it could be the case that type-based induction might have been more difficult than color- and shape-based induction. Nevertheless, we deliberately chose highly familiar fruit and vegetables for both the 'cut' and 'whole' categories, featuring items like a banana, tomato, and strawberry. It is reasonable to assume that children have similar familiarity with both whole and sliced tomatoes due to their common presence and usage. The same applies consistently across the other stimuli employed in our study. In future research, we can explore this aspect further by, for instance, prompting children to identify and name the F/V depicted in the picture (e.g., a piece of tomato) and verifying whether they correctly identify it as a 'tomato'. Moreover, we did not include general cognitive abilities as covariates in our study. It is worth noting that children who demonstrated a lack of comprehension of the task or

instructions during testing were excluded, resulting in a final sample consisting of typically developing children for whom additional tests (language and cognitive abilities) were not administered due to the measures taken to ensure understanding. However, all children were able to understand the tasks. So, this probably did not play a role in our sample. However, it is encouraged for future research to incorporate a measure of cognitive ability, as this might influence the performance of the children. It is also important to note that the present study did not examine causality. In theory, an immature food categorization might lead to higher food rejection, but the inverse can also be true: if children are less picky and consume a wide variety of foods, they might gain more experience with eating, leading to better categorization skills. Future research should consider real-life settings, examine causality, incorporate real food, and explore different categorization methods to gain deeper insights into children's food preferences. By addressing these limitations, we can better understand the factors influencing food acceptance and rejection in children, contributing to the promotion of healthier eating habits among young individuals.

Conclusion

In summary, the findings of this study suggest that category-based induction and memory of fruit and vegetables are not related to food rejection in children. This is in line with some previous studies (Pickard et al., 2021; Pickard et al., 2023; Rioux, Lafraire, et al., 2018a, 2018b; Rioux et al., 2016) but not with others (Foinant et al., 2022a; Pickard et al., 2023; Rioux, Lafraire, et al., 2018b). The inconsistent results suggest that induction probably plays a small role in the rejection of fruit and vegetables. It is unlikely that interventions solely focusing on these factors would be effective in promoting healthy eating behaviors in children. Perhaps different types of categorizations that children may use (i.e., safe vs unsafe or familiar vs unfamiliar) are more important for children. Previous research has demonstrated that exposing

children to foods and encouraging them to engage in food-related activities (e.g., play with food) can enhance their acceptance of new foods (Roberts et al., 2022). Thus, promoting familiarity with food is probably more crucial than induction and memorization of foods based on abstract features rather than perceptual features.

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Chapter 3

Investigating Shared Cognitive Traits in Autism Spectrum Disorder and Picky Eating

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ABSTRACT

Objective: Picky eating is common among children with autism spectrum disorder (ASD) and can lead to nutritional deficiencies with negative health consequences. Because ASD traits and picky eating often co-occur, it remains unclear whether similar cognitive mechanisms underlie picky eating in typically developing children. This study examined whether cognitive traits associated with ASD are also linked to picky eating in typically developing children. It was hypothesized that higher levels of picky eating would be associated with lower cognitive flexibility, less developed theory of mind (ToM), a local processing bias, and higher parent-reported ASD traits.

Methods: A cross-sectional study was conducted with 198 children aged 4-6. The children completed three tasks to measure cognitive flexibility (Dimensional Change Card Sort), ToM, and global-local processing preferences. Receptive vocabulary was measured to control for general cognitive ability. Parents completed the Autism Spectrum Quotient (AQ-10) and Child Food Rejection Scale (CFRS) to assess ASD traits and picky eating, respectively.

Results: Contrary to expectations, no significant relationship was found between picky eating and the cognitive traits studied. However, a small negative correlation was found between ToM and the picky eating subscale, suggesting that higher picky eating levels may be related to lower ToM abilities.

Conclusion: These findings suggest that in typically developing children, ASD-related traits are probably not strongly associated with picky eating, except for ToM. Future research is needed to examine if social factors appear to play a more crucial role in picky eating.

Keywords: picky eating, autistic traits, cognitive flexibility, global-local processing, theory of mind, young children.

INTRODUCTION

Picky eating is a common issue among young children. Between 8% and 54% of preschool-aged children are identified as picky eaters, and it is most commonly observed between the ages of 2-6 years (Chao, 2018; Mascola et al., 2010; Taylor et al., 2015). Picky eating is particularly associated with a reduced intake of fruit and vegetables, which can limit essential nutrient intake and negatively affect development (Lafraire et al., 2016; Zickgraf & Schepps, 2016). For instance, picky eating has been linked to lower body weight and nutritional deficiencies (Jani et al., 2024). Over time, persistent refusal to eat fruit and vegetables may elevate the risk of chronic conditions such as eating disorders, cardiovascular diseases, and certain types of cancer (Chamoun et al., 2018; Göbel et al., 2023). Although many children eventually grow out of picky eating, for some these, behaviors persist into adulthood, increasing the risk of an unhealthy lifestyle (van den Brand et al., 2023). Because early eating habits tend to track into later life (Nicklaus et al., 2005), establishing a healthy diet early on is crucial. Picky eating typically involves the refusal of both familiar and unfamiliar foods (Dovey et al., 2008) and may include avoiding specific textures or requiring particular rituals (e.g., specific sauces) (Smith et al., 2005). This broader concept of picky eating also includes food neophobia, where foods are rejected preemptively, often based on visual cues, before they are even tasted (Dovey et al., 2008; Lafraire et al., 2016).

Notably, picky eating is particularly prevalent among children and adults with autism spectrum disorder (ASD) (Elsayed et al., 2022; Harris et al., 2023; Postorino et al., 2015). ASD is a neurodevelopmental condition that typically manifests in early childhood and is characterized by difficulties in social communication and interaction, as well as restrictive and repetitive behaviors, interests, and activities (American Psychiatric Association, 2013). These characteristics have

been linked to feeding difficulties (Page et al., 2021). Studies indicate that between 46% and 89% of children with ASD experience feeding challenges (Ledford & Gast, 2006; Mayes & Zickgraf, 2019; Sharp & Postorino, 2017) with affected children being five times more likely to have feeding difficulties than their typically developing peers and three times more likely than children with other neurodevelopmental disorders, such as Down syndrome (Sharp et al., 2013; Sharp & Postorino, 2017). These observations suggest that picky eating occurs frequently among children with ASD.

While these findings provide important insights into picky eating in children with ASD, it remains unclear whether similar cognitive mechanisms relate to picky eating in typically developing children. Recent research suggests that certain autistic traits, even in children without an ASD diagnosis, may be associated with picky eating behaviors. For example, Zhang et al. (2024) found that children aged 4–6 with higher levels of autistic traits were more likely to display ARFID-related eating behaviors, including picky eating in response to sensory characteristics of food. This raises the possibility that cognitive characteristics linked to picky eating in ASD, such as rigidity or reduced cognitive flexibility, may also relate, albeit to a lesser extent, to picky eating in typically developing children. If this is the case, interventions that are effective for addressing picky eating in children with ASD, such as behavioral parent training, might also be beneficial for these children (Johnson et al., 2015; Sharp et al., 2014). Taken together, these considerations show the relevance of examining whether cognitive traits associated with ASD are related to picky eating in children without an ASD diagnosis, which is the focus of the present study.

In the present study, we focus on three cognitive characteristics commonly associated with ASD, namely reduced cognitive flexibility, difficulties in theory of mind (ToM), and a preference for local over

global information processing (Albein-Urios et al., 2018; Memari et al., 2013; Page et al., 2021; Van Eylen et al., 2011). These constructs were selected based on prior research in children with ASD and their plausible links to picky eating. Although they may reflect partially overlapping aspects of a broader cognitive style, they are typically treated as distinct constructs in the literature (Pellicano, 2010; Rajendran & Mitchell, 2007). Each construct was therefore considered individually, as they are likely to capture different aspects of cognitive traits that may relate to picky eating in typically developing children

Cognitive flexibility, the ability to adapt thoughts and behaviors in response to changing situations (Cragg & Chevalier, 2012), is often reduced in children with ASD and is thought to relate to rigid eating patterns. Similar difficulties have been observed in typically developing picky eaters, who often display highly specific and inflexible food preferences (Zickgraf et al., 2022; Zickgraf & Schepps, 2016). Foinant et al. (2022) found that children aged 3–6 years with higher levels of picky eating scored lower on a cognitive flexibility task, whereas working memory and inhibition were unrelated. These findings may suggest that difficulties in adapting and applying food-related information may underlie rigid eating behaviors, for example, insisting on eating a vegetable only with a specific sauce. Supporting this, Zohar et al. (2020) reported that lower cognitive flexibility at age 3 predicted picky eating at age 8. These studies provide a rationale for examining cognitive flexibility as a potential contributor to picky eating in typically developing children.

ToM refers to the ability to understand others' mental states and perspectives (Baron-Cohen, 2000; Carlson et al., 2013). Difficulties in ToM, often observed in children with ASD, can reduce social facilitation, the tendency to engage in behaviors observed in others, such as eating when others eat (Clayton, 1978; Lafraire et al., 2016). Children with impaired ToM may struggle to interpret cues from caregivers

or peers about the safety or desirability of new foods, potentially increasing picky eating. For instance, research shows that young children are more likely to try new foods when they observe positive reactions from familiar others (Addessi et al., 2005; Blissett, 2018; Salvy et al., 2008), but children with lower ToM abilities may benefit less from such social learning. Further emphasizing this link, Cancellieri et al. (2022) found that positive social interactions and emotions related to food significantly increased children's willingness to eat. These findings suggest that understanding and internalizing others' emotional reactions to food, an ability related to ToM, may play an important role in developing positive food-related experiences. Therefore, children with less developed ToM may struggle to form such associations, making them more prone to picky eating. Examining ToM in this context helps clarify whether social-cognitive processes may relate to picky eating in typically developing children.

Global-local processing reflects a bias toward focusing on details (local) rather than the overall picture (global) and is often heightened in children with ASD (Koldewyn et al., 2013; Plaisted et al., 1999; Sharp et al., 2013). A local processing bias describes attention directed toward specific features of a stimulus rather than integrating them into a coherent whole (Booth & Happé, 2018). While sometimes discussed within the broader framework of weak central coherence, global–local bias represents a more specific perceptual dimension, emphasizing perceptual processing rather than contextual or inferential integration (Happé & Frith, 2006; Koldewyn et al., 2013). In eating behavior, a local processing bias may explain why some children fixate on small, undesired elements of food. For example, a child might reject a meal, such as macaroni, because of a single visible ingredient. This heightened attention to individual components, rather than the whole dish, can relate to picky eating. Picky eaters often refuse foods 'on sight', highlighting the potential role of visual perception in selective eating (Taylor & Emmett, 2019).

A preference for local over global processing is not unique to ASD and has also been observed in eating disorders (Lang et al., 2014). Such patterns, enhanced local processing, and reduced global integration, support the idea that detail-focused perceptual styles may relate to picky eating. These findings suggest that examining global–local processing in typically developing children may help clarify how perceptual styles relate to picky eating.

Despite potential links between picky eating in children and cognitive flexibility, ToM, and global-local processing, these relationships have not been examined or, when considering cognitive flexibility, need to be replicated. The present study, therefore, aims to investigate how these three cognitive constructs relate to picky eating in children. The primary hypothesis is that more picky eating children display higher levels of cognitive traits associated with ASD compared to less picky eating children. To explore this overarching hypothesis, three specific hypotheses have been formulated: (1) Children who demonstrate more picky eating have lower levels of cognitive flexibility compared to children demonstrating less picky eating. (2) Children who demonstrate more picky eating show more local processing, whereas children who demonstrate less picky eating show more global processing. (3) Children who demonstrate more picky eating have lower levels of ToM compared to children demonstrating less picky eating. In addition, we examine how these cognitive traits relate to parent-reported ASD traits. This study aims to clarify how cognitive traits related to ASD manifest in relation to picky eating in typically developing children.

METHODS

Ethical approval

The present study received approval from the Ethics Committee of Maastricht University's Faculty of Psychology and Neuroscience (ERCPN-OZL-233-11-02-2021_S13). Before testing started, written consent was obtained from parents for their child's participation, and any child's choice not to participate was fully respected. The study was preregistered on AsPredicted (157295) and can be accessed at https://aspredicted.org/QJS_B2S. All analyses were conducted following the specified protocol.

Participants

The study was conducted at primary schools with children aged 4 to 6 years. The children who participated in this study were enrolled in primary schools located in the South and Central regions of the Netherlands. The sample size for the study was calculated using G*Power 3.1 software for a multiple linear regression analysis (fixed model, R^2 increase) with an effect size of 0.15 and an alpha level of 0.05. With power levels ranging from 0.80 to 0.95, the required sample size ranges from 85 to 129 participants. To accommodate potential outliers, measurement errors, and smaller effect sizes, we set a target to recruit up to 160 participants. Given the methodology of inviting entire school classes, the final number of participants exceeded our initial target. In total, 199 parents provided consent for their children to participate. However, one parent who provided informed consent did not complete the questionnaires. So, the study included 198 children (94 girls, 104 boys) with a mean age of 4.7 years (SD = 0.65, range 4-7 years) and an average age of 61.6 months (SD = 7.3, range 48-84 months). Ultimately, a total of 179 children were tested in the study, as three children were absent due to illness, one was on holiday, and 15 were not tested due to time constraints. In addition, six children were excluded because they lacked adequate Dutch language

proficiency or were distracted during the tasks. Additionally, five children were excluded from the ToM task because they either did not understand the task or were too shy to participate. A further 18 participants were excluded from the ToM task due to subsequent changes in the study protocol. One child was excluded from the Global-Local task due to a score below the chance level on the selective attention task, suggesting a potential misunderstanding of the task as a whole. Finally, 32 participants were excluded from the cognitive flexibility (DCCS) task due to a programming error, and an additional 26 participants were excluded because they did not meet the performance criterion of achieving at least 5 out of 6 correct responses in both the pre-switch and post-switch phases. Consequently, the results presented for the various tasks involve different numbers of participants, as detailed in Table 1.

Study Design

The study employed a cross-sectional correlational design with the primary outcome being picky eating. In the present study, "picky eating" is measured by the Child Food Rejection Scale (CFRS), which was completed by parents. The predictor variables included the children's cognitive flexibility score, measured with the DCCS task, ToM score, global-local processing score, and the Autism Spectrum Quotient (AQ) – 10 score. Additionally, age, gender, and the receptive vocabulary (RV) score, which was used to control for general cognitive ability, were included as control variables.

This study was an individual study, although most of the participating children were also involved in a separate study conducted on a different day. The two studies have distinct dependent and independent variables, except for the CFRS, which is used in both studies. Detailed information about the other study is available on AsPredicted (157297) at https://aspredicted.org/H9T_6D8, titled 'Is hunger the best spice for novel foods?'

Measurements

Demographic variables

A parental questionnaire was used to collect key demographic information, including the child's age (in years), gender (boy or girl), relationship to the child, and color blindness status. If a child was colorblind with respect to the colors used in the tasks, they were excluded from the study based on this criterion. The questionnaire also recorded the child's date of birth, which was used to calculate their age in months, based on the date of testing.

Child Food Rejection Scale (CFRS)

The CFRS (Rioux et al., 2017) assessed children's picky eating. The CFRS is an 11-item parent-report questionnaire (α = .87) that measures picky eating in children aged 2-7 years, translated into Dutch by Hendriks-Hartensveld et al. (2023). The questionnaire includes two subscales: food neophobia, which has 6 items, and picky eating, which consists of 5 items. Caregivers rated their agreement with statements related to their child's food neophobia (e.g., "My child only likes familiar foods") and picky eating (e.g., "My child arranges food on the plate") on a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree). The global picky eating score ranges from 11 to 55, with higher scores indicating greater levels of picky eating. In particular, picky eating scores range from 5 to 25(α = .69), and food neophobia (α = .87) scores range from 6 to 30 (Rioux et al., 2017). The picky eating subscale showed modest internal consistency (α = 0.69), slightly below the conventional threshold of 0.70, but this is still considered acceptable for brief scales of only 4–5 items (Vaske et al., 2017).

Autism Spectrum Quotient (AQ) – 10

The AQ – 10 (Allison et al., 2012; Auyeung et al., 2008) is a parent-report questionnaire used to measure autistic traits in children. It is an adapted and shortened version of the AQ-child (Auyeung

et al., 2008) and is intended for children aged 4-11 years (α = .90). Healthcare professionals use the AQ-10 to determine whether a child should be referred for a full autism spectrum disorder (ASD) screening. The AQ-10 was translated into Dutch by Stehouwer and Bezemer (2023) and used in the present study. The questionnaire includes 10 descriptive statements that assess five areas associated with ASD: social interaction (e.g., "My child finds it hard to make new friends"), communication ("My child does not know how to keep a conversation going with peers"), attention to detail ("My Child often notices small sounds when others do not"), attention switching ("My child finds it easy to go back and forth between different activities") and imagination ("When my child is read a story, my child finds it difficult to work out the character's intentions and feelings"). Each item is rated on a 4-point Likert scale: definitely agree, slightly agree, slightly disagree, definitely disagree. Only one point can be scored per question, with a maximum score of 10. Higher scores indicate more autistic traits. One point is scored for "definitely agree" or "slightly agree" on items 1, 5, 7, and 10, and for "definitely disagree" or "slightly disagree" on items 2, 3, 4, 6, 8, and 9. A total score of 6 or above suggests the need for referral to a specialist for a complete diagnostic assessment (Allison et al., 2012; Auyeung et al., 2008). In addition to the standard dichotomous scoring method, we also checked the continuous scoring approach using the full 4-point Likert scale to increase sensitivity to individual differences. The AQ-10 showed modest internal consistency in this sample (Cronbach's α = .58). Although slightly below the commonly accepted range for brief scales, such values may still be considered adequate in exploratory research settings (Vaske et al., 2017). Given its use as a screening tool for autistic traits rather than a diagnostic assessment, the scale was deemed appropriate for this study, though its psychometric limitations should be acknowledged.

Dimensional Change Card Sort (DCCS)

The DCCS (Zelazo, 2006) is used to measure executive functioning, especially cognitive flexibility. The task is a rule-shifting task that involves sorting cards based on different criteria: first by color, then by shape, and finally by both in a combined "border version". The task included five phases, with two consistent target images: a red rabbit and a blue boat. In each trial, the child sees one target and two answer options (i.e., a blue rabbit and a red boat). The child must choose the answer that matches the target according to the current rule.

In the familiarization phase, children are introduced to the two target stimuli (a red rabbit and a blue boat) on an iPad and informed that they will be playing a game with these images. Next, in the demonstration phase, children are instructed to sort cards based on color and practice with two example trials, receiving feedback on their answers. The instruction given was: "Here is a blue picture; where does it belong?" During the pre-switch phase, children continue to sort a series of six cards by color without receiving feedback, using the same instruction. In the post-switch phase, the sorting criterion shifts to shape, where children sort six cards by matching the shape of the target, with the instruction: "Here is a rabbit; where does it belong?" Again, no feedback is provided. Finally, in the border version phase, the task combined the color and shape sorting rules in 12 trials. The same targets (red rabbit and blue boat) are used, but some targets have a black border around them. If a target has a border, children have to sort by color; if there is no border, they have to sort by shape. The instruction given was: "There is a border/no border around this, so then you have to play the color/shape game; where does it belong?" The location of the correct answer (right or left) was randomized.

The DCCS border score (ranging from 0 to 12), based on the number of correct responses in the border version phase, was used in the

main analyses. In addition, a composite DCCS score (ranging from 0 to 24), combining performance across the pre-switch, post-switch, and border phases, was reported to provide a more comprehensive developmental overview of cognitive flexibility within the sample. Higher scores indicated greater cognitive flexibility. The task took approximately 10 minutes to complete (Zelazo, 2006).

Theory of Mind (ToM) test

The ToM test (Muris et al., 1999) assessed children's ability to understand and analyze the behavior of others by recognizing their mental states (i.e., desires and beliefs). In this test, the experimenter explained various scenarios to the child and then asked a related question that the child must answer. The original ToM test consists of 14 items with a total of 78 questions, covering three successive stages of ToM development: precursors of ToM (e.g., emotion recognition), first manifestations of a real ToM (e.g., understanding of false belief), and mature aspects of ToM (e.g., second-order beliefs). In the present study, items 3-6 were used because of the specific age range of the children in the study, focusing on the first two stages of ToM development (Westby & Robinson, 2014). These items measure emotion recognition (e.g., the child needs to point to a boy who is looking happy), first-order belief (e.g., the child needs to guess where a dog will search for its bone after it has been changed location from its original location), and false belief (e.g., the child listens to a story about a girl, who receives a jacket she dislikes but pretends to like, and is then asked questions to assess their understanding of the girl's belief versus reality).

The task was presented on paper and explained by the experimenter. Children answered the questions in various ways, such as pointing, explaining, or responding with yes or no. There were 15 questions in total, each scored as either correct (1) or incorrect (0), with all items weighing equally in the overall score (Muris et al., 1999). So, the

score could range from 0-15, with higher scores indicating a better developed ToM (α = .69). The task took approximately 5 minutes to complete.

Global-local processing task

The Global-Local task (Koldewyn et al., 2013) measured children's default attention. This means whether the child has a preference for focusing on global or local information when given a free choice. The task was divided into two consecutive tasks: a divided attention task and a selective attention task. The task began with a practice trial to ensure that the children understood the concept of the task. In this trial, children were shown a dog (the target object) and asked to verbally identify it. After they responded, two additional pictures (another dog and a plant) were added to the bottom of the display. The children were then asked to indicate which picture most closely resembled the target object (see Figure 1).

The divided attention task consisted of six trials where children were shown hierarchical shapes, such as a big square made of smaller triangles. Below the target shape, two answer options were presented: one matching the target at the global level (e.g., a big square made of small squares) and the other at the local level (e.g., a big triangle made of small triangles). The children were asked to indicate which option most resembled the target, based on their opinion. Children were not given any guidance on whether to match the hierarchical stimulus at the global or local level, nor did they receive feedback on their choices (see Figure 2). A global preference was scored as 0, while a local preference was scored as 1. Thus, the total score could range from 0 to 6, with higher scores indicating a stronger local preference. The duration of the task was approximately 5 minutes (Koldewyn et al., 2013).

The selective attention task was used to assess whether children could categorize hierarchical stimuli at both the global and local levels when instructed to do so. The scores from this task were not used in the final analysis as they were not relevant to the objective of this study. Previous research has shown that children with ASD do not have a deficit in processing global features; they are capable of doing so when required but tend to show a preference for local-level processing (Koldewyn et al., 2013; Suzanne Scherf et al., 2008). The stimuli consisted of hierarchical shapes of triangles, squares, and crosses. The task included 12 trials in total, with six trials in the global block and six in the local block. Each correct answer was scored as 1, and each incorrect answer was scored as 0. The selective attention score ranged from 0 to 12 (in total) or from 0-6 (per type of block), with higher scores indicating better categorization ability (Koldewyn et al., 2013). For the present study, children were excluded from this task if they had a score of 3 (i.e., chance level) or lower per level, which was the case for one participant at the global level.

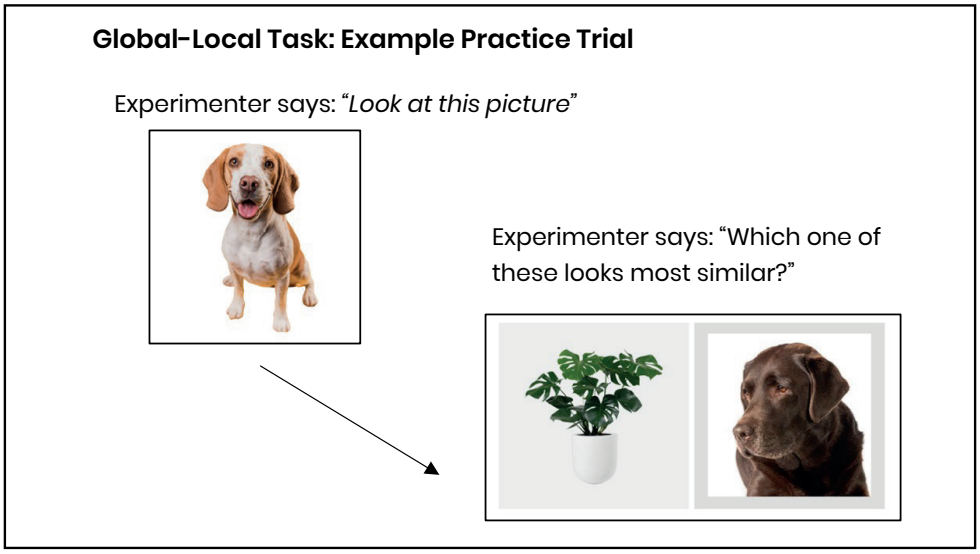


Figure 1. Example of the practice trial of the Global-Local task

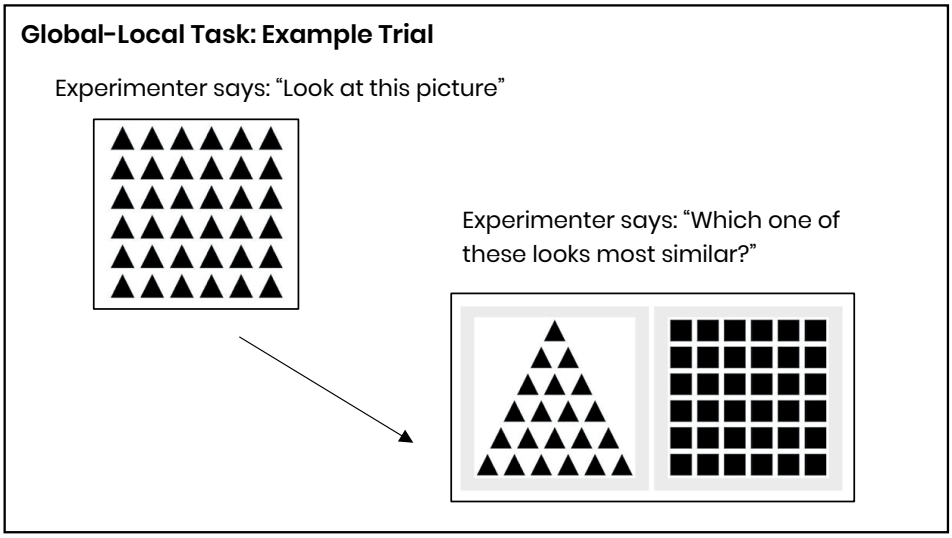


Figure 2. Example of the divided attention task of the Global-Local task

Receptive vocabulary (RV) task

The RV task is a subset of the WPPSI-III-NL (Hendriksen & Hurks, 2009), which is an instrument that measures general cognitive capacities of young children and was used in the current study as a control variable. The RV task consisted of 31 items, where the child was shown four pictures at a time and asked to point to the picture that corresponded to a word read aloud by the experimenter (e.g., swimming). Depending on the child's response, the test either progressed to a more difficult question, moved to an easier question, or stopped after too many mistakes consecutively. Scores ranged from 0 to 31, with higher scores indicating better receptive vocabulary. The reliability and validity of this subtask are rated from adequate to good (Hendriksen & Hurks, 2009). The task took approximately 5 minutes to complete.

Procedure

The experimenters introduced themselves to the entire class and provided a brief overview of the testing procedure. Each child was tested individually in a quiet area at their school, using an iPad to

collect data via Qualtrics. The experiment began with an explanation that the children would be playing four games: the Dimensional Change Card Sort (DCCS), Theory of Mind (ToM), Global-Local, and Receptive Vocabulary (RV) tasks, which were presented in a random order. Each session lasted approximately 20-30 minutes per child. After completing the experiment, each child received a vegetable diploma as a token of appreciation and was then returned to the class.

Data analysis

Data collection was carried out using Qualtrics on an iPad and analyzed with IBM SPSS software (version 27.0, SPSS Inc., Chicago, IL). First, boxplots and descriptive statistics were used to examine the dataset for outliers, and none were identified. Descriptive statistics were calculated for all variables, and assumptions were checked.

To investigate whether children who show more picky eating display elevated levels of cognitive traits associated with ASD compared to children with lower levels of picky eating, the following analyses were conducted. First, a correlational analysis was performed involving all variables of interest: CFRS, AQ-10, DCCS, ToM, Global-Local (divided attention score), age, gender, and RV score. Second, a multiple linear regression analysis was carried out, with picky eating as the outcome variable and all ASD-related measures (AQ-10, DCCS, ToM, Global-Local) as predictors, while controlling for age, gender, and RV score.

An exploratory analysis was also conducted to investigate whether the relationship between picky eating and ASD traits differed between the two subscales of the CFRS questionnaire: food neophobia and picky eating. Based on previous research by Foinant et al. (2022), it was expected that the relationship between picky eating and cognitive flexibility (DCCS) would be stronger for the subscale food neophobia than for the subscale picky eating.

RESULTS

Correlational Analysis of Picky Eating and Cognitive Traits Associated with ASD

The results of the parental questionnaires (CFRS and AQ-10) and the child's tasks (DCCS, ToM, Global-Local, and RV) are summarized in Table 1. A correlational analysis exploring the relationships between all these measures and age (in months) and gender (boy or girl) is presented in Table 2. Pearson correlations showed no significant correlations between the CFRS score and all other measures. Pearson correlations showed significant correlations between AQ-10 and DCCS; AQ-10 and ToM; DCCS and ToM; DCCS and RV; DCCS and age (months); ToM and RV; ToM and age (months); RV and age (months).

Table 1.
Parental questionnaires and outcome child tasks

	N	Minimum	Maximum	Mean	Std. dev.
CFRS	198	11	55	30.13	7.51
AQ-10	198	0	7	2.26	1.49
DCCS border	114	3	12	8.46	2.55
DCCS composite	114	15	24	20.22	2.59
ToM	150	4	15	9.85	2.66
Global-Local	172	6	12	7.92	2.19
RV	170	10	27	20.38	3.84

Notes. CFRS: Child Food Rejection Scale; AQ-10; Autism Spectrum Quotient – 10; DCCS: Dimensional Change Card Sort; ToM: Theory of Mind; RV: Receptive Vocabulary.

Table 2.

Variables		1	2	3	4	5	6	7	8	9	10
1.	CFRS		.064	-.012	-.138	.004	-.014	-.065	-.061	.940**	.890**
2.	AQ-10			-.181*	-.192*	.027	.009	.010	.003	.077	.034
3.	DCCS border				.437**	-.158	.411**	.458**	-.114	.088	-.144
4.	ToM					-.005	.302**	.437**	-.057	-.096	-.168*
5.	Global-Local						-.012	-.061	.000	-.024	.041
6.	RV							.317**	-.036	.039	-.083
7.	Age (months)								.067	-.010	-.125
8.	Gender									-.022	-.101
9.	CFRS-N										.682**
10.	CFRS-P										

Notes. CFRS: Child Food Rejection Scale; AQ-10; Autism Spectrum Quotient – 10; DCCS: Dimensional Change Card Sort; ToM: Theory of Mind; RV: Receptive Vocabulary; CFRS-N: CFRS food neophobia subscale; CFRS-P: CFRS food pickiness subscale; $^{*}p < 0.05$, $^{**}p < 0.001$.

Pearson correlations between parental, child, and control measures

Multiple Linear Regression Analysis of Picky Eating and ASD-related Measures

A multiple regression analysis was conducted to examine whether a combination of variables could predict picky eating. The CFRS score served as the outcome variable, while the AQ-10, DCCS, ToM, and Global–Local scores were used as predictors. Age, gender, and RV were included as control variables. The model explained 3.5% of the variation in the CFRS score, which was not significant ($F(7, 102) = 0.53$, $p = .810$). None of the control variables contributed meaningfully to the model (gender: $t = 0.14$, $p = .889$; age in months: $t = -0.53$, p = .559; RV: $t = -0.32$, $p = .749$). The analysis further showed that DCCS ($\beta = .108$, $t = 0.88$, $p = .380$), ToM ($\beta = -.110$, $t = -0.99$, $p = .310$), Global–Local ($\beta = .076$, $t = 0.76$, $p = .447$), and AQ-10 ($\beta = .109$, $t = 1.07$, $p = .286$) were not significantly associated with the CFRS score.

All Bayes factors ($BF_{10} < 1$) favored the null model, indicating weak-to-moderate evidence for the absence of predictive effects.

Exploratory analyses

The two subscales of the CFRS, food neophobia and food pickiness were added as pre-registered explorative analyses (see Table 2). A statistically significant negative correlation was found between ToM and the food pickiness subscore (r = –.168, p = .039), indicating that higher levels of food pickiness were associated with lower ToM abilities. Consistent with this correlation, the corresponding regression analysis (including the other cognitive factors) showed that ToM was significantly associated with food pickiness (t = -2.10, p = .041). To complement these findings, a Bayesian regression analysis yielded a Bayes factor of 1.35 for ToM, indicating that the data were only slightly more consistent with a model including ToM than with the null model. This suggests that the evidence for this association is weak and should be interpreted with caution.

In addition to the total ToM score, we conducted exploratory analyses to examine whether specific ToM subcomponents were differentially associated with picky eating. The subcomponents included emotion recognition (8 items), first-order beliefs (4 items), and false belief understanding (3 items). Picky eating (total and subscale scores) showed small but significant negative correlations with the false belief subscale (r = –0.21, p = .012; r = –0.20, p = .013, respectively), while no significant associations were found with the emotion recognition or first-order belief subscales.

Further exploratory analyses indicated that results remained nonsignificant when using the continuous AQ-10 score (β= .094, t = 1.05, p = .296). Given the significant correlation between ToM and the picky eating subscale, we also examined the socially oriented AQ-10 items in an exploratory manner. Notably, item 5 ("My child doesn't know how to keep a conversation going with peers") showed a slightly significant correlation with the global picky eating score (r = .17, p = .019), neophobia (r = .15, p = .043), and the picky eating subscale (r =

.17, p = .020). Since higher scores on this item reflect greater difficulty with peer communication, these positive correlations might suggest that increased social communication difficulties may be linked to higher levels of picky eating. Although these findings may tentatively suggest a link between social communication difficulties and picky eating behavior, they are exploratory, with small effect sizes and no correction for multiple testing, and should therefore be viewed as hypothesis-generating rather than confirmatory (Hooper, 2025). Lastly, using the composite DCCS score instead of the border DCCS score in our regression analyses did not materially change the results (β = .056, t = 0.51, p = .614).

DISCUSSION

The present study examined whether cognitive traits associated with ASD relate to picky eating in typically developing children aged 4–6 years. This investigation was motivated by the high prevalence of picky eating in children with ASD and the possibility that similar cognitive characteristics might contribute to picky eating in children without an ASD diagnosis. We focused on three cognitive traits hypothesized to relate to picky eating: cognitive flexibility (assessed via the DCCS task), ToM (assessed via a ToM task), and a preference for local over global information processing (assessed via the Global-Local task). Picky eating was measured using the Child Food Rejection Scale (CFRS), ASD traits were assessed with the AQ-10, and general cognitive ability was estimated with the receptive vocabulary subtest of the WPPSI.

Contrary to our expectations, no significant relationship was found between picky eating and the ASD-related cognitive traits examined in this study (cognitive flexibility, ToM, and global-local processing). These findings differ from those of Zhang et al. (2024), who reported an association between ASD traits and picky eating. This discrepancy

may reflect differences in measurement focus: the present study targeted cognitive/behavioral traits, whereas Zhang et al. (2024) emphasized social traits. It is also possible that ASD-related traits play little or no role in picky eating among typically developing children, and that other factors, such as sensory sensitivity, temperament, or parenting, may be more influential. It is also important to acknowledge that these cognitive constructs (cognitive flexibility, ToM, and global–local processing) are theoretically related rather than entirely independent; executive functions can support or influence ToM and perceptual processing. Each construct was considered individually, as they are likely to capture different aspects of cognitive traits that may relate to picky eating in typically developing children.

The results regarding cognitive flexibility differed from those of Foinant et al. (2022), who reported a relationship between picky eating and cognitive flexibility. Both studies used the DCCS task, but the present study employed the border version with 12 trials (six color, six shape), calculating a total score based on correct responses (Zelazo, 2006). In contrast, Foinant et al. (2022) used a double vector scoring method combining accuracy and reaction time across 30 trials (24 frequent color, six infrequent shape), potentially increasing sensitivity to individual differences in cognitive flexibility. Accuracy was based on correct responses across pre-switch, post-switch, and mixed trials. To ensure comparability, we recalculated a similar total flexibility score for our border-version data, but the results remained non-significant. While the larger number of trials and inclusion of reaction time in Foinant et al. (2022) may increase sensitivity, the absence of an effect in our study suggests no robust relationship in this sample. Differences with Zohar et al. (2020), who found that cognitive flexibility at age 3 (assessed via the parent-reported BRIEF-P Emotional Control subscale) predicted picky eating at age 8, may reflect the distinction between performance-based and questionnaire-based measures of cognitive flexibility. Despite these null findings in the present study,

the DCCS task correlated positively with AQ-10 scores, ToM, age, and receptive vocabulary, supporting its validity as a measure of cognitive flexibility in this typically developing sample.

When examining the relationship between picky eating and children's ToM abilities, no significant association was found for the overall CFRS score. However, a more detailed pre-registered analysis of the CFRS subscales revealed a small negative correlation between the food pickiness subscale and ToM, suggesting that children with lower ToM abilities tend to be slightly more picky. However, this effect was small and should be interpreted with caution. Exploratory analyses suggested that false belief understanding may play a more specific role in the link between socio-cognitive functioning and picky eating, though this finding should be interpreted cautiously, given that the subscale was based on only three items. Similarly, one socially oriented AQ-10 item related to conversational difficulty correlated with picky eating, tentatively suggesting altogether that social-cognitive aspects may be more relevant to picky eating than broader ASD-related traits, a possibility also supported by Zhang et al. (2024). This relationship may also be influenced by additional factors such as social facilitation, parenting styles, or parental eating behaviors, which were not measured here but could affect children's food acceptance (Blissett, 2011; Scaglioni et al., 2018). Future research could examine whether ToM mediates the relationship between autistic traits and picky eating. If such mediation exists, it may indicate that children with higher autistic traits experience greater difficulty with the social-cognitive aspects of eating, such as understanding that others enjoy certain foods, recognizing social expectations to try them, or interpreting encouragement from caregivers during meals. These challenges could make it harder to engage in flexible eating behaviors during shared mealtimes, potentially contributing to more rigid or selective food preferences. Interventions enhancing ToM might therefore indirectly reduce picky eating by promoting more

flexible social responses during mealtimes. Furthermore, ToM scores also correlated positively with age and the RV task, consistent with developmental expectations (Schneider et al., 2014) and supporting task validity. Although the ToM task was age-appropriate and previously validated, future studies could include explicit control questions to better assess task comprehension, particularly in younger children (Hutchins et al., 2008).

Contrary to our expectations, no significant relationship was found between children's global–local processing preferences and their levels of picky eating. Thus, a stronger local processing bias was not associated with higher picky eating. Moreover, the Global–Local task did not correlate with any other measures in the study, which may indicate that the task was not sensitive enough or too brief to capture a reliable processing preference with only six trials. Although there is no clear consensus regarding the optimal number of trials, some studies use fewer (Koldewyn et al., 2013) and others substantially more (Hayward et al., 2018; Hupp & Souther, 2014; Plaisted et al., 1999). These six trials were selected to provide a range of possibilities while ensuring a clear measure of the child's natural preference, without being influenced by strategies that might emerge in longer tests, such as switching between global and local responses (Koldewyn et al., 2013). At the same time, it is also possible that global–local processing simply does not play a substantial role in picky eating among typically developing children. This interpretation aligns with previous inconsistent findings in the literature, as several studies have also failed to find a clear link between global–local processing and ASD traits (Van der Hallen et al., 2015). Together, these results highlight that both methodological and conceptual explanations should be considered when interpreting the null effects.
Finally, no significant relationship was found between children's ASD-related traits and picky eating, contrasting with studies reporting high feeding difficulties in children with ASD (Elsayed et al., 2022;

Harris et al., 2023; Postorino et al., 2015). This may reflect the sample composition of typically developing children with generally low AQ-10 scores (M = 2.26), with only about 3% above the referral cutoff, limiting variability and the likelihood of detecting associations. This suggests that ASD-related traits may not strongly influence picky eating in typically developing populations, or that a threshold of traits may need to be exceeded before such a link emerges. Despite the null findings, AQ-10 scores correlated negatively with DCCS and ToM, supporting the sensitivity and validity of these cognitive measures in capturing individual differences within this sample. Future studies could examine children with a broader range of ASD traits to clarify potential relationships with picky eating.

General cognitive functioning was assessed using the receptive vocabulary subtest of the WPPSI, chosen to provide a brief estimate of cognitive ability while avoiding overlap with other tasks. Vocabulary scores correlated significantly with age, cognitive flexibility (DCCS), and ToM, supporting the validity of these measures in this sample. However, a single subtest offers only a limited view of general cognition. Future research would benefit from using more comprehensive assessments, such as multiple subtests of the WPPSI, to better capture the full range of cognitive abilities.

In conclusion, the present study suggests that picky eating in typically developing children is not significantly related to ASD-related traits, namely cognitive flexibility, ToM, and global-local processing. While previous research by Foinant et al. (2022) reported lower cognitive flexibility in picky eaters, our findings indicate that such ASD-related traits may not be central contributors to picky eating in this population. It remains possible that methodological differences, such as task versions or scoring, could partly explain discrepancies with prior studies; however, it is also plausible that these cognitive traits simply play a limited role in picky eating among typically developing children.

A small association between ToM and the picky eating subscale, along with a correlation between picky eating and a socially oriented AQ-10 item (reflecting conversational difficulties), tentatively points to social-cognitive aspects as potentially more relevant than broader ASD-related traits. However, these effects were small and should be interpreted cautiously. Other factors, such as sensory sensitivity, temperament, or parental feeding practices, may also influence food rejection behaviors in typically developing children (Farrow & Coulthard, 2012; Nederkoorn et al., 2015). Interventions targeting sensory experiences, repeated exposure to foods (Nekitsing et al., 2018), responsive parenting approaches (Blissett, 2011; Podlesak et al., 2017), or involving children in food-related activities (Roberts et al., 2022) may support healthier eating habits, regardless of cognitive traits. Continued research is needed to clarify the cognitive and social mechanisms underlying picky eating, to guide the design of effective interventions for supporting healthy eating in children (van den Brand et al., 2023).

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Chapter 4

I See What You Taste: The Influence of Social Learning on Food Acceptance in Children

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ABSTRACT

Picky eating is common in childhood and is characterized by limited diet quality. Because children acquire food preferences partly through social learning, such as observing others' emotional and behavioral responses to food, this study examined whether individual differences in children's ability to process facial, taste, and social-related cues are associated with picky eating and fruit and vegetable (FV) consumption. A total of 273 child–parent pairs were recruited at the NEMO Science Museum in Amsterdam. Parents reported on their own picky eating as well as their child's picky eating using a questionnaire. A proxy of FV intake of both children and parents was assessed using skin carotenoid measurements with the Veggie Meter. Children completed tasks assessing facial emotion recognition, basic taste identification, recognition of tastes via others' facial expressions, and a social modeling task. Results showed that parental picky eating and parental Veggie Meter scores were positively related to child picky eating and child Veggie Meter scores. Poorer identification of basic tastes was associated with higher levels of child picky eating, even after controlling for parental picky eating and parental Veggie Meter scores. Facial emotion recognition and recognition of tastes via others' facial expressions were not associated with child picky eating or child Veggie Meter scores. In the social modeling task, most children selected food paired with a positive facial expression; however, this choice was unrelated to emotion/taste recognition, child picky eating, or child Veggie Meter scores. Together, these findings suggest that picky eating in children is related to poorer taste identification rather than to difficulties in recognizing facial expressions. Interventions aimed at improving children's taste-related processing or reducing taste-related uncertainty may therefore help support healthier eating patterns in picky children.

Keywords: Picky eating, Fruit and vegetable intake, Social learning, Modeling, Parents.

INTRODUCTION

Picky eating is common in childhood and is characterized by the rejection of familiar and unfamiliar foods, resulting in a limited dietary variety (Dovey et al., 2008; Taylor et al., 2015). Picky eating is consistently associated with lower fruit and vegetable (FV) intake and may therefore reduce dietary quality during a critical period of development (Brown et al., 2016; Galloway et al., 2003; Taylor & Emmett, 2019). Although picky eating is often regarded as a normative developmental phase, substantial individual differences exist in its severity and persistence (Nicklaus et al., 2005; Taylor et al., 2015). One specific component of picky eating is food neophobia, defined as the reluctance to try unfamiliar foods (van den Brand et al., 2023). For some children, picky eating decreases over time, whereas for others it remains stable and contributes to less healthy eating patterns later in life (Cardona Cano et al., 2015; Mascola et al., 2010; Mikkilä et al., 2004). Prevalence estimates range widely from 5.6 to 50 percent (Taylor et al., 2015). Despite its high prevalence, the mechanisms underlying picky eating remain insufficiently understood.

Children's eating behavior develops within a social context in which foods are offered and consumed (Birch & Fisher, 2000; Salvy et al., 2008). In early childhood, parents and caregivers function as the primary social models due to their central role in food provision and shared meals, while siblings and peers become increasingly influential as children grow older (Addessi et al., 2005; Birch & Fisher, 2000; Lumeng et al., 2008). Consistent with this, research shows that parental picky eating as well as parental FV intake are associated with similar eating patterns in children (Coulthard & Blissett, 2009; Fisher et al., 2002; Gibson et al., 1998; Miller et al., 2011; Wardle et al.,

2005; Yalcin, 2022). Observational learning plays a central role in this process, as children use others' eating behavior to infer the safety, palatability, and social acceptability of foods (Birch & Fisher, 1998; Gahagan, 2012). Watching a model (e.g., a mother) consume a food has been shown to increase children's willingness to taste and consume both initially disliked and unfamiliar foods, as well as familiar foods. (Addessi et al., 2005; Greenhalgh et al., 2009; Harper & Sanders, 1975; Hendy & Raudenbush, 2000). These effects are thought to operate by reducing food-related uncertainty and anxiety, thereby lowering resistance to tasting and helping food acceptance (Hendy & Raudenbush, 2000).

When observing others eat, children are exposed not only to information about food consumption but also to cues about food enjoyment conveyed through facial expressions (Rosenstein & Oster, 1988; Steiner et al., 2001). These expressions communicate whether a food is experienced as pleasant or unpleasant and may even provide information about specific sensory properties, such as bitterness or sweetness (Oster, 2005; Yildirim et al., 2023). Facial expressions, therefore, constitute a salient source of social information during eating interactions, particularly when children are confronted with unfamiliar foods for which they lack prior experience. Previous research has demonstrated that others' facial expressions while eating can influence food acceptance (Barthomeuf et al., 2012). When foods are paired with eaters expressing pleasure, neutrality, or disgust/dislike, differences in food acceptance emerge; positive expressions increase children's willingness to eat disliked foods, whereas expressions of disgust reduce their desire to eat liked foods (Barthomeuf et al., 2012). Similarly, in a study on raw broccoli, 4–6-year-old children who observed unfamiliar adults expressing positive facial expressions while eating the vegetable showed greater tasting and higher intake compared with children who viewed a video in which the adult model was present, but no food was shown or eaten.

(Edwards et al., 2022). However, as no negative expression condition was included and the comparison was made with a no-food control, the effects may partly reflect exposure rather than facial expressions alone. In contrast, research in adults has shown that observing negative facial expressions during consumption can reduce liking of the modelled food (Edwards et al., 2024). Taken together, these findings suggest that affective social cues play an important role in shaping food-related responses. Through such cues, children may form expectations about foods, reducing uncertainty and increasing their willingness to taste. Consequently, positive affective modeling may facilitate the acceptance of new or less preferred foods.

However, for children to learn from others, facial expressions need to be correctly interpreted. In everyday interactions, such expressions are often subtle rather than extreme (Bould et al., 2008). Children differ in their capacity to recognize facial expressions and to infer others' taste experiences from these cues (de Bordes et al., 2021). Children who are less able to interpret affective facial cues may therefore benefit less from food modeling, which could contribute to higher levels of picky eating and lower FV intake. They may also be less responsive to subtle facial expressions displayed by a model. For example, children with autism spectrum disorder are often picky eaters and show difficulties in interpreting facial expressions (Mirizzi et al., 2025; Yeung, 2022).

Therefore, the present study examined whether individual differences in children's ability to interpret eating-related social information are associated with child picky eating and child Veggie Meter scores. It was hypothesized that poorer facial emotion recognition would be associated with higher levels of child picky eating (H1a) and lower child Veggie Meter scores (H1b). It was further hypothesized that children's ability to recognize basic tastes from others' facial expressions would be associated with higher levels of child picky

eating (H2a) and lower child Veggie Meter scores (H2b).

Furthermore, we expected children to select food from a model with a positive facial expression more frequently than from models with neutral or negative facial expressions (H3a). This preference was expected to be less pronounced in children with poorer facial emotion recognition, poorer basic taste recognition from others' facial expressions, higher levels of child picky eating, and lower child Veggie Meter scors (H3b).

Because children's eating behavior develops within a family context, parental picky eating and parental Veggie Meter scores were included as covariates to account for parental eating behavior. Even when children are able to accurately recognize taste-related facial expressions, growing up with picky eating parents may reinforce negative food evaluations, whereas exposure to parents who consume a wide variety of foods may facilitate more positive food learning. We hypothesized positive associations between parental and child picky eating, and between parental and child Veggie Meter scores (H4–H5). Finally, we hypothesized that children's facial emotion recognition and basic taste recognition from others' facial expressions would remain significantly associated with child picky eating after controlling for parental eating behavior (H6).

METHODS

Ethical approval and preregistration

Ethical approval for the study was received by the Ethics Committee of the Faculty of Psychology and Neuroscience (ERCPN) at Maastricht University (OZL-233-11-02-2021_S20). Informed consent was obtained from parents prior to their children's participation; children between 12 and 14 also provided written consent, while children under 12 provided oral consent. The study was preregistered on AsPredicted

(251324) https://aspredicted.org/ji5za7.pdf, and all statistical analyses were conducted in line with the preregistered protocol. An additional preregistered task (i.e., interpretation bias) is reported elsewhere.

Participants

An a priori power analysis using G*Power 3.1 (Faul et al., 2007) showed that detecting an increase in explained variance of .15 required 142–199 participants (power = .80–.95) with a Bonferroni-corrected alpha of .0167 (for three outcomes). Participation was voluntary, and children could withdraw at any time. Children were eligible to participate if they were between 6-14 years old, accompanied by a parent or caregiver, and were Dutch-speaking.

A total of 288 children were initially tested at the NEMO Science Museum in Amsterdam, so participating families were visitors from various regions of the Netherlands. After merging the child and parent datasets, several cases were removed to ensure accurate matching between parent and child. In addition, one child was excluded due to limited Dutch proficiency, and for another child the final task (i.e., social modeling food choice) was omitted due to concentration difficulties. Finally, three child–parent pairs were excluded because the parent reported eating together with the child less than once per week. The final sample consisted of 273 child–parent pairs, representing 183 unique parents. The children (132 girls, 141 boys) were between 6 and 14 years old (M = 8.86, SD = 2.04). Most children attended regular primary education (86.8%), with smaller proportions enrolled in secondary education (11.7%), special education (1.1%), or other types of schooling (0.4%). Their parents (125 female, 58 male) ranged in age from 31 to 58 years (M = 41.34, SD = 4.69). Parental education levels were high, with 82.0% of parents holding an (applied) university degree. When asked how often they share dinner with their child(ren), the majority of parents reported doing so daily (62.3%), followed by 18.6% who shared the meal six times per week. The remaining 19.1% reported sharing the

evening meal less frequently. Additionally, 12.6% of parents reported smoking occasionally or regularly.

Materials

Demographic information

Several demographic variables were measured as possible covariates, given their potential association with children's picky eating and FV intake. Parents reported the child's age and gender, their own age and gender, their education level (used as a proxy for socioeconomic status), the number of weekly shared meals, the child's school level, and the parental smoking status (i.e., as this may interfere with Veggie Meter). In addition, children also provided their own age and gender.

Child Food Rejection Scale (CFRS)

Child picky eating was measured with a Dutch translation (Hendriks-Hartensveld et al., 2023) of the parental Child Food Rejection Scale (CFRS) (Rioux et al., 2017). The questionnaire consists of 11 items, including two subscales: picky eating (5 items: e.g., "My child refuses certain foods due to their texture") and food neophobia (6 items: e.g., "My child is constantly looking for familiar foods"). Each statement was rated by a caregiver on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Item scores were then summed to create a total child picky eating score of the child, ranging from 11 to 55, with higher scores indicating greater child picky eating. Previous research using the Dutch version reported good internal consistency (α = .89) (Hendriks-Hartensveld et al., 2023), which was also observed in the present study (α = .90).

Adult Picky Eating Questionnaire (APEQ)

Parental picky eating was measured with a Dutch translation (Koenders et al., 2024) of the Adult Picky Eating Questionnaire (APEQ) (Ellis et al., 2017). The questionnaire consists of 16 items assessing

eating behavior across four subscales: meal presentation (α = .79, e.g., "I prefer foods of a particular color"), food variety (α = .77, e.g., "My usual diet lacks a variety of food groups"), meal disengagement (α = .81, e.g., "I usually feel that I have something better to do than eating"), and taste aversion (α= .84, e.g., "I reject bitter foods, even if they are only slightly bitter") (Ellis et al., 2017). Each item was rated on a 5-point Likert scale ranging from 1 (never) to 5 (always). A mean parental picky eating score was calculated for each participant by averaging their responses across all 16 items, with higher scores reflecting higher levels of parental picky eating. The APEQ showed good internal consistency in the present sample (α= .79).

Veggie Meter

To obtain a proxy of FV intake, skin carotenoid concentrations were measured using the Veggie Meter® (Longevity Link Corp., Salt Lake City, UT, USA) in both children and their parents. The Veggie Meter is a reflection spectroscopy device that non-invasively measures skin carotenoid levels, which are transformed into a score ranging from 0 to 800. This score serves as a proxy for FV consumption over the past two months (Mayne et al., 2013). The device has been validated against food frequency questionnaires and resonance Raman spectroscopy in both adults and children, and its measurements are not affected by personal characteristics such as age, sex, or skin color (Ermakov et al., 2018; May et al., 2020; Nagao-Sato et al., 2021; Okada et al., 2024; Rush et al., 2020). For each participant, the index finger of the non-dominant hand was scanned. Before scanning, the fingertip was cleaned with a disposable wipe. Three consecutive scans were performed, with a five-second interval between each measurement. The Veggie Meter device averaged these three scans to generate a single score (Martinelli et al., 2021). This average score was used in the analyses and reflects an individual's skin carotenoid levels, with higher scores indicating greater FV intake (Ermakov et al., 2016; May et al., 2020; Radtke et al., 2021). In a Dutch sample, mean Veggie Meter

scores were 319.0 in children and 335.0 in adults (van Lier et al., 2026).

Facial emotion recognition

To assess children's ability to recognize emotional facial expressions, participants completed a facial emotion recognition task consisting of 12 trials. Stimuli were taken from the Amsterdam Dynamic Facial Expression Set (van der Schalk et al., 2011). The task comprised two parts. In the first part, children were shown individual photographs of faces displaying one of the six basic emotions (happy, sad, angry, scared, disgusted, or surprised) and were asked to identify how the person in the picture felt. The first trial always depicted a happy expression; the other trials were randomly presented. After six trials, the task shifted to the second part, in which the procedure was reversed. Children were presented with an emotion label and asked to select the corresponding facial expression from a set of five photographs, representing the same six emotions used in the first part. For all trials, no feedback was given. The task lasted approximately five minutes. Accuracy across both parts of the task was combined into a single facial emotion recognition score, ranging from 0 to 12, with higher scores indicating better emotion recognition.

Basic taste recognition from others' facial expressions

This task was performed to measure the ability of children to recognize basic taste from others' facial expressions. Children were presented with four trials, each featuring a different model displaying facial expressions while tasting sweet, sour, salty, or bitter stimuli. The photographs were taken while the models were actually tasting these stimuli. In each trial, four photographs of the same model were shown, each corresponding to one of the four basic tastes. Prior to the task, children were informed that the models had tasted foods representing these tastes (i.e., sugar for sweet, lemon for sour, salt for salty, and strong coffee for bitter). They were instructed to identify which photograph matched a given taste (e.g., "Which picture

shows the model tasting something sweet?"). The order of trials and the presentation of facial expressions within each trial were randomized (see Figure 1). A total basic taste recognition from others' facial expressions score was calculated by summing the number of correct responses, with higher scores indicating better recognition of basic tastes in others. The full task took approximately four minutes to complete, and no feedback was provided during the task.

"In which photo did this woman taste something bitter?"



"In which photo did this woman taste something salty?"



Figure 1. Example of the taste recognition task. Participants were asked to identify the photo in which the woman tasted a specific taste (e.g., bitter or salty) based on her facial expression. In the first example, the upper left photo is the correct response; in the second example, the lower left photo is the correct response.

Basic taste strip identification

This task assessed children's ability to recognize basic tastes (Taste test 25, Burghart, Wedel, Germany). The task was included as a control measure for the taste recognition from others' facial expressions task, as recognizing taste-related expressions is assumed to depend on prior sensory experience with those tastes (Rosenstein & Oster, 1988; Steiner et al., 2001). Children were randomly presented with four ODOFIN taste strips (Taste test 25, Burghart, Wedel, Germany) impregnated with one of the basic tastes (sweet, sour, salty, and bitter). The children were asked to place each strip on their tongue and indicate which taste they perceived, being told the four taste options. After each response, the strip was discarded before continuing with the next trial. For all trials, no feedback was given. A total basic taste strip identification score was computed by summing the number of correct responses (range 0 – 4), with higher scores reflecting better basic taste identification.

Social modeling of food choice

To measure the influence of social cues on children's food choices, a brief social modeling task was performed. The participating children were shown photographs of the same model displaying three different facial expressions (slightly negative, neutral, and slightly positive), each paired with a covered cup. Children were told that the model had just tasted the food inside the cup, without knowing that all cups actually contained the same food (a small piece of carrot). Participants were then asked to choose one of the cups. The primary outcome was the chosen cup, coded as 1 when the cup paired with the positive expression was selected and 0 when one of the other two cups was chosen. The social modeling of food choice score was then calculated across participants. After selecting a cup, children were given the option to taste the food; food acceptance was measured using a 6-point scale ranging from 1 (physical refusal) to 6 (swallowing) (Blissett et al., 2016). However, the food acceptance score

was not included in further analyses. The order of the photographs was randomized to control for potential order effects, and the task took approximately two minutes per participant.



Figure 2. Photographs used in the social modeling food choice task, shown from left to right: slightly negative, neutral, and slightly positive.

Procedure

The study was conducted in a quiet, designated room at NEMO Science Museum in Amsterdam. Parents and their child(ren) who were interested in participating were welcomed by an experimenter, who briefly explained the study and verified eligibility (parent/legal guardian present, able to understand the Dutch language, and child aged 6–14 years). Eligible parents received an information letter and provided informed consent on an iPad, children aged 12-14 also provided informed consent on the iPad. Parent and child were then directed to separate testing stations within the same room, separated with a half-closed curtain, to prevent influence. During busy periods, families could sign up for a later time slot.

The parent completed the study with one experimenter, while the child was tested simultaneously by another. When two parents were present, the parent most familiar with the child's eating behavior completed the questionnaires. Parents first completed demographic questions regarding themselves and their child on an iPad and informed the experimenter when they reached the Veggie Meter section. Parents then completed questionnaires on their own

eating behavior (APEQ) and that of their child(ren) (CFRS). After finishing, parents were thanked and could optionally leave contact information for follow-up research.

The child was tested individually at a separate table. After reporting age and gender, the child was informed that they would complete several short tasks on an iPad, some involving tasting. The child then completed the tasks in a fixed order: emotion recognition, taste identification, taste recognition, and social modeling food choice. The interpretation bias task (reported elsewhere) was administered between basic taste recognition from others' facial expressions and social modeling of food choice tasks. The experimenter supervised all tasks, entered responses when necessary, and provided neutral encouragement without giving evaluative feedback. Afterward, the child completed the Veggie Meter assessment following the same measurement procedure as for parents. Upon completion, the child was thanked and reunited with the parent(s).

Data analysis

Data collection was carried out using Qualtrics on an iPad and analyzed with IBM SPSS software (version 27.0, SPSS Inc., Chicago, IL). Data were screened for outliers (values > 2.5 SD or < −2.5 SD), and values exceeding these thresholds were Winsorized, including a total of 5 outliers across all measures (i.e., Veggie Meter parental, Veggie Meter child, and APEQ). Descriptive statistics for the tasks were calculated.

First, potential covariates were examined in relation to the three main outcomes (child picky eating, child Veggie Meter, and social modeling of food choice). Child age was negatively associated with child picky eating ($r(269) = -.16, p = .008$) and was therefore included as a covariate in all child picky eating (CFRS) analyses. Social modeling of food choice was significantly associated with child gender, with

girls more often choosing the positive model (X^2 = 6.82, p = .009); gender was therefore included as a covariate in all social modeling of food choice analyses. Based on theoretical considerations, parent-related variables were also examined. Parental education ($\rho(181)$ = -.22, p = .002) and parental smoking status ($t(181)$ = 3.58, p < .001) were significantly associated with parental Veggie Meter scores, with non-smokers scoring higher, and were included as covariates in analyses involving parental Veggie Meter. All other examined covariates (i.e., parent age and gender, school level child, and weekly shared dinners) showed no significant associations and were excluded to increase statistical power (Miller & Chapman, 2001).
Second, Pearson correlations were calculated among all study variables: child and parental picky eating, child and parental Veggie Meter scores, facial emotion recognition, basic taste strip identification, and basic taste recognition from others' facial expressions. For the binary social modeling of food choice variable, independent-samples t-tests were conducted.

Finally, the hypotheses were tested using regression models. Hierarchical regression analyses were conducted for child picky eating, and child Veggie Meter, and a hierarchical logistic regression was used for social modeling of food choice. The relationship between parent and child measures was examined in a reduced dataset (n = 183) that included only one child per parent (i.e., siblings were removed), as entering the same parent twice could bias the results. The data of the oldest child was always retained. Significant covariates, as mentioned above, were included in the first step of the models. For all analyses, a Bonferroni-corrected significance level of p < .0167 was used to correct for three main outcome measures (i.e., child picky eating, child Veggie Meter, and social modeling of food choice).

RESULTS

Descriptive statistics

Table 1 presents the descriptive statistics of the parental and child picky eating and Veggie Meter scores, as well as the child behavioral tasks.

Table 1.
Descriptive statistics of child behavioral tasks and parental questionnaires.

Variables	N	Mean	SD	Minimum	Maximum	% Correct
Child picky eating (CFRS)	271	29.70	8.75	11	54	
Parent picky eating (APEQ)	183	29.85	6.84	16	47	
Child Veggie Meter	273	349.92	89.83	122	577	
Parent Veggie Meter	183	353.21	88.07	133	576	
Facial emotion recognition	273	10.01	1.57	4	12	
Emotion recognition (part 1)	273	4.72	1.06	2	6	
Happy						98.9
Scared						60.8
Surprised						86.8
Disgusted						55.3
Angry						77.3
Sad						92.7
Emotion identification (part 2)	273	5.30	0.88	2	6	
Happy						98.5
Scared						86.4
Surprised						83.2
Disgusted						77.3
Angry						85.3
Sad						98.5
Basic taste strip identification	270	3.35	1.03	0	4	
Sweet						87.9
Sour						82.0
Salty						80.1
Bitter						84.9
Basic taste recognition from others facial expressions	273	2.33	0.86	0	4	45.8
Sweet						77.3
Sour						24.2
Salty						85.3
Bitter						
Social modeling of food choice - slightly positive	268			0	1	75.0

Notes. CFRS = Child Food Rejection Scale; APEQ = Adult Picky Eating Questionnaire; SD = standard deviation.

Correlations among study variables

Table 2 shows the correlations between the outcome measures and the variables of interest. Independent sample *t*-tests regarding the binary social modeling of food choice showed no significant association with child picky eating ($t(267) = -0.77$, $p = .441$), child Veggie Meter ($t(269) = 0.82$, $p = .411$), basic taste strip identification ($t(266) = -0.65$, $p = .517$), and basic taste recognition from others' facial expressions ($t(269) = -0.26$, $p = .799$). The social modeling of food choice was significantly related to facial emotion recognition ($t(269) = -2.18$, $p = .030$). Children who selected the cup corresponding to the positive model showed slightly higher emotion recognition scores ($M = 10.14$, $SD = 1.54$) than children who selected the other models ($M = 9.66$, $SD = 1.66$). This indicates that children with better facial emotion recognition were more likely to choose what the positive model had eaten.

Table 2.

Pearson correlations among all study variables

Variables	1	2	3	4	5	6	7
Child measures							
1. CFRS		-.21**	.03	-.18**	-.20**	.29**	-.07
2. Veggie Meter child			.06	.12	.07	-.21**	.41**
3. Facial emotion recognition				.19**	.09		
4. Taste identification					.17**		
5. Taste recognition							
Parent measures							
6. APEQ							-.29**
7. Veggie Meter parent							

Notes. CFRS: Child Food Rejection Scale; APEQ: Adult Picky Eating Questionnaire; *$p = < .05$, **$p = < .01$.

Associations with child picky eating

A hierarchical linear regression examined whether facial emotion recognition, basic taste strip identification, and basic taste recognition from others' facial expressions predicted child picky eating, controlling

for child age. The final model significantly predicted child picky eating, R^2 = .066 (6.6%), $F(4, 263) = 4.64$ p = .001. In Step 1, child age accounted for 2.6% of the variance and was a significant negative predictor (β = -.16, p = .008), indicating that older children were less picky eaters. Facial emotion recognition (Step 2) did not significantly contribute to the model (ΔR^2 = .005, p = .258). Unpredictably, the control measure of basic taste strip identification (Step 3), significantly improved the model, explaining an additional 2.1% of the variance (ΔR^2 = .021, p = .016), with poorer performance associated with higher picky eating scores (β = -.15). Basic taste recognition from others' facial expressions (Step 4) was not significant after Bonferroni correction (ΔR^2 = .015, p = .043) but showed a trend-level contribution (β = -.13), indicating that poorer basic taste recognition from others' facial expressions was related to higher picky eating.

Additionally, the hierarchical regression analysis was repeated to examine the role of the parental eating behavior. Child age, parental picky eating, and parental Veggie Meter scores were included as covariates. To avoid non-independence of observations, analyses were conducted on a reduced dataset including one child per parent. The final model significantly predicted child picky eating, R^2 = .16 (16%), $F(6, 173) = 5.50$, $p < .001$. In Step 1, child age, parental picky eating, and parental Veggie Meter scores explained 12.3% of the variance in child picky eating (R^2 = .12), $F(3, 172) = 8.22$, $p < .001$. Older child age was associated with lower child picky eating (β = -.18, p = .011), whereas higher parental picky eating was associated with higher child picky eating (β = .32, $p < .001$); parental Veggie Meter scores were not significant (β = .01, p = .883). Facial emotion recognition (Step 2) did not significantly improve model fit (ΔR^2 = .004, p = .400). Basic taste strip identification (Step 3) significantly improved model fit, explaining an additional 2.7% of the variance (ΔR^2 = .027, p = .016), with poorer basic taste identification associated with higher child picky eating (β = -.17). Basic taste recognition from others' facial expressions (Step 4) did

not significantly contribute to the model (ΔR^2 = .007, p = .243).

Associations with child Veggie Meter

A hierarchical linear regression examined whether facial emotion recognition, basic taste strip identification, and basic taste recognition from others' facial expressions, predicted child Veggie Meter child scores. The final model did not significantly predict child Veggie Meter, R^2 = .015, $F(3, 266)$ = 1.38, p = .357. None of the predictors contributed significantly to the model. Facial emotion recognition, basic taste strip identification, basic taste recognition from others' facial expressions, and social modeling of food choice explained no significant additional variance (ΔR^2s ≤ .010, ps ≥ .096).

Associations with social modeling of food choice

Table 1 showed that 75% of the children chose the food paired with the positive model. There were no differences in carrot intake between children choosing the slightly positive model (N = 201, M = 5.05, SD = 1.69), the neutral model (N = 48, M = 4.94, SD = 1.80), and the slightly negative model (N = 19, M = 5.11, SD = 1.73). Although carrot intake in the social modeling task was not a primary variable of interest, it showed a small but significant negative correlation with child picky eating, $r(181)$ = -.16, p = .027. This suggests that higher levels of child picky eating are associated with lower actual carrot intake in children.

A hierarchical logistic regression was conducted to examine whether facial emotion recognition, basic taste strip identification, basic taste recognition from others' facial expressions, child picky eating and child Veggie Meter predicted social modeling of food choice, while controlling for child gender. All predictors were included sequentially. The final model was statistically significant, $X^2(4)$ = 10.41, p = .034, and explained 5.7% of the variance (*Nagelkerke* R^2 = .057).

In Step 1, child gender significantly predicted social modeling of food choice, B = 0.74, SE = 0.30, p = .012, OR = 2.09, *95% CI* [1.17, 3.73], indicating that girls were more likely than boys to choose the food shown by the positive model. In Step 2, facial emotion recognition did not significantly improve model fit, $\Delta X^2(1) = 3.80$, p = .051, although a trend-level association was observed, B = 0.17, SE = 0.09, p = .052, OR = 1.19, *95% CI* [1.00, 1.41], suggesting that children with higher facial emotion recognition scores were more likely to choose the positive model. Basic taste strip identification and basic taste recognition from others' facial expressions did not improve model fit and were not significant predictors (ΔX^2s ≤ 0.016, ps ≥ .899). Similarly, child picky eating and child Veggie Meter scores did not significantly improve the prediction of social modeling of food choice (ΔX^2s ≤ 0.96, ps ≥ .328).

Parent–child associations in picky eating and FV intake

A linear regression analysis examined whether parental picky eating predicted child picky eating. The model was significant, $F(1, 179) = 18.11$, $p < .001$, explaining 9.2% of the variance (R^2 = .092). Higher levels of parental picky eating were associated with higher child picky eating scores (β = .30, $p < .001$).

A linear regression analysis tested whether parental Veggie Meter scores predicted child Veggie Meter scores The model was significant, $F(1, 179) = 36.03$, $p < .001$, explaining 16.1% of the variance (R^2 = .161), indicating that parental Veggie Meter scores were associated with higher child Veggie Meter scores (β = 0.41, $p < .001$).

DISCUSSION

The present study examined whether children's ability to interpret eating-related social information is associated with child picky eating and child Veggie Meter (a proxy of FV intake). Results showed

that basic taste recognition from others' facial expressions was initially correlated with child picky eating, but this effect became non-significant after controlling for parental eating behavior. Facial emotion recognition was not related to child picky eating or child Veggie Meter. While most children preferred foods paired with a positive facial expression in the social modeling of food choice task, this preference was unrelated to facial emotion recognition or basic taste recognition from others' facial expression, child picky eating, or child Veggie Meter. Finally, parental and child picky eating, as well as parental and child Veggie Meter socres, were positively associated. Unpredictably, poorer identification of basic tastes (i.e., sweet, sour, bitter, and salty) was associated with higher levels of child picky eating, and this association remained significant after controlling for parental picky eating and parental Veggie Meter.

The finding that poorer basic taste strip identification was associated with higher levels of child picky eating suggests that picky eating may be linked to differences in sensory perception rather than difficulties in interpreting social cues. Children who have more difficulty identifying basic tastes such as bitter, sour, salty, and sweet may experience food as more unpredictable or unclear, which could make them less willing to try new foods and contribute to picky eating. The association between basic taste strip identification and child picky eating remained significant even after accounting for parental picky eating and parental Veggie Meter, suggesting that children's taste processing abilities may play a role beyond parental eating behaviors. However, the reverse relationship is also possible: children who are picky eaters and consume a limited variety of foods may have less exposure to different tastes, which in turn may reduce their ability to identify tastes. Longitudinal research is needed to clarify the direction of this association. Research on sensory identification in relation to picky eating is limited and shows mixed findings. One study found no association between children's taste identification

and food liking (Ervina et al., 2020), whereas another study reported that better smell identification was associated with lower levels of food neophobia (Sorokowska et al., 2024). A broader body of research has highlighted positive associations between sensory factors and picky eating (Blissett et al., 2016; Farrow & Coulthard, 2012; van den Brand et al., 2025; Zickgraf et al., 2022), although this literature has mainly focused on sensory sensitivity and taste reactivity rather than sensory identification abilities.

Interestingly, the ability to recognize basic tastes from others' facial expressions was not significantly associated with child picky eating once parental factors were taken into account. Nevertheless, children in this study were generally able to recognize certain tastes from facial expressions, particularly bitter and sour, while sweet recognition was still above chance level, and salty was notably difficult (around chance level). This pattern is supported by research showing that basic tastes trigger distinct facial responses, some more recognizable than others. For example, newborns display clear, identifiable reactions to bitter, sour, and sweet tastes, while studies in adults have found recognizable expressions for bitter and sour. By contrast, salty and sweet tastes generally produce less distinctive facial cues (Bredie et al., 2014; Rosenstein & Oster, 1988). Although these skills did not relate to children's own eating behavior in this study, the findings are still interesting. They suggest that picky eating may depend more on how children experience and interpret tastes themselves, rather than on how well they understand taste cues in others.

Contrary to expectations, facial emotion recognition was not associated with child picky eating or child Veggie Meter. This suggests that child picky eating may not reflect a deficit in socio-emotional information processing. Although previous research has emphasized the role of affective cues in shaping children's

food acceptance (Barthomeuf et al., 2012; Edwards et al., 2022), the present results indicate that the ability to recognize basic emotions in faces may not be a central mechanism underlying individual differences in everyday eating behavior. It is also possible that general emotion recognition abilities, as measured in the present study, are insufficiently specific to capture the processes involved in food-related social learning. Standardized tasks typically assess the identification of clear, prototypical emotional expressions (e.g., happiness, sadness, anger), whereas in everyday eating contexts facial expressions are often subtle, dynamic, and embedded within broader social interactions. Consequently, children may rely less on explicit emotion labeling skills and more on contextual information, prior taste experiences, and repeated exposure when deciding whether to accept or reject foods (Nekitsing et al., 2018). The absence of associations may therefore suggest that the socio-cognitive skills assessed by general emotion recognition tasks lack the specificity needed to explain variation in food-related behaviors. Moreover, links between facial emotion recognition and eating difficulties may be more pronounced in clinical populations (Kerr-Gaffney et al., 2020), whereas in typically developing children, variability in general facial emotion recognition may not meaningfully translate into differences in eating patterns.

Consistent with prior research (Barthomeuf et al., 2012; Edwards et al., 2022), most children selected food paired with a positive facial expression in the social modeling of food choice task, indicating sensitivity to affective social cues during food choice (i.e., carrot). However, this preference was not related to children's facial emotion recognition, basic taste recognition from others' facial expressions, child picky eating, or child Veggie Meter scores. Nevertheless, children who selected the positive model tended to show somewhat better facial emotion recognition, suggesting that better recognition of emotional cues may increase responsiveness to positive

social signals. This suggests that positive facial expressions may encourage children to choose the food paired with them. The lack of associations with the other measures may reflect characteristics of the task itself. The social modeling task involved a single, brief exposure and measured an immediate choice rather than learning or intake over time. Such a design may be insufficiently sensitive to capture individual differences that are more likely to emerge through repeated exposure or sustained social interactions (Nekitsing et al., 2018). Furthermore, the strong overall preference for the positive model suggests a possible ceiling effect, limiting variability in the outcome measure. Importantly, real-life eating interactions are typically more complex and dynamic than the experimental context used in the present study. During shared meals, children are exposed not only to facial expressions but also to verbal comments, consumption behavior, tone of voice, and relational dynamics. These multifaceted social processes may amplify or attenuate modeling effects in ways that are not fully captured by a brief laboratory task. It is therefore possible that individual differences in socio-emotional or taste-related processing are more relevant in real-life situations, where social cues develop over time and occur within meaningful relationships.

The strong associations between parental and child picky eating, as well as between parental and child Veggie Meter scores, replicate previous work by showing the importance of the family context in children's eating behavior (Coulthard & Blissett, 2009; Fisher et al., 2002; Gibson et al., 1998; Miller et al., 2011; Wardle et al., 2005; Yalcin, 2022). In the present study, parental picky eating was positively associated with children's picky eating, and children's Veggie Meter score was strongly associated with parental Veggie Meter scores. In addition, higher levels of picky eating were associated with lower Veggie Meter scores in both parents and children, suggesting that picky eating is reflected in actual dietary intake. In addition, higher

parental picky eating was linked to lower FV intake in children. Together, these findings emphasize the central role of the family context in shaping both children's eating styles and dietary intake. However, because of the cross-sectional design, the direction of these associations cannot be determined. Parental eating behavior may influence children through food availability and shared eating practices, but children's eating behavior may also affect parental food choices and meal preparation (Costa & Oliveira, 2023). Moreover, it is important to note that these associations may not only reflect shared environmental influences but also shared genetic factors. Previous research has provided evidence for a genetic component in picky eating and food preferences (Koenders et al., 2024; Nas et al., 2025). Therefore, the similarities between parents and children observed in the present study may be explained by a combination of environmental and genetic influences.

Strengths and limitations

Strengths of this study include the large, well-powered sample, preregistration of hypotheses, and the use of a multi-method approach combining behavioral tasks, validated questionnaires, and a proxy of FV intake using the Veggie Meter.

Several limitations should be acknowledged. First, the cross-sectional design precludes causal conclusions about the directionality of associations between the measures. Second, some tasks, particularly basic taste recognition from others' facial expressions and the social modeling of food choice task, involved a limited number of trials, which may have reduced sensitivity to individual differences. A ceiling effect was found in the basic taste strip identification task, with 67% of the children achieving the maximum score. This limited the variation in scores and may have reduced the strength of the association. However, the task still showed a significant relationship with child picky eating. Third, the basic taste recognition from others'

facial expressions and the social modeling of food choice tasks were developed for the present study and have not been formally validated. Although these tasks were based on commonly used and validated paradigms, their psychometric properties have not yet been established and should be examined in future research. Finally, the sample consisted largely of highly educated parents, which may limit generalizability to more diverse populations. Higher parental education has been linked to lower levels of child picky eating, potentially due to greater nutrition-related knowledge and/or more access to healthy food (Cardona Cano et al., 2015; Cooke et al., 2004; Machado et al., 2016). Although no association with picky eating or child Veggie Meter was observed in the present study, future research should examine whether these findings replicate in more socioeconomically diverse, lower-educated samples, where picky eating may be more prevalent.

Conclusion

Together, these findings indicate that picky eating in children is associated with poorer basic taste strip identification rather than with difficulties in processing social cues. Although children generally respond to positive social signals during a food choice, facial emotion recognition and basic taste recognition from others' facial expressions appear to play no role in explaining variability in child picky eating and child Veggie Meter. In contrast, parental eating behavior and parental Veggie Meter scores were strongly related to children's eating patterns, showing the importance of the family context and/or genetics. Together, these results suggest that interventions may be most effective when they combine a focus on children's direct taste experiences, such as repeated exposure and reducing uncertainty about flavors, while also addressing parents' own eating patterns and the foods they make available at home.

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Chapter 5

Is Hunger the Best Sauce for Unfamiliar Foods? A Study Investigating the Effect of Hunger on Young Children's Food Intake of a Familiar and Unfamiliar Fruit

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ABSTRACT

Sufficient fruit and vegetable intake is crucial for healthy development, yet many children fail to meet the recommended levels, partly due to food rejection. This study aimed to identify an effective, easy-to-implement strategy to increase fruit intake in children by examining the impact of hunger on the consumption of a familiar and unfamiliar fruit. Additionally, it explored the moderating role of picky eating within this relationship. A total of 177 children aged 4-6 were assigned to a hungry condition (food-deprived for 3-4 hours) or a non-hungry condition (food-deprived for less than 30 minutes). The children were then asked to taste either a familiar fruit (apple) or an unfamiliar fruit (lychee), with up to 9 pieces available for tasting. It was hypothesized that children in the hungry condition would consume more fruit compared to those in the non-hungry condition, and that intake would be higher for the familiar fruit than the unfamiliar fruit. Additionally, the effect of hunger on intake was expected to be moderated by picky eating, with a weaker effect in children who were more picky eaters. Results from a 2x2 ANOVA showed hunger significantly increased fruit consumption, regardless of familiarity, and the familiar fruit was consumed more than the unfamiliar fruit. No interaction between hunger and fruit familiarity was found, and picky eating did not moderate the relationship between hunger, familiarity, and intake. These findings suggest that mild hunger can be an effective strategy to increase children's fruit intake, and offering fruits when children are hungry may promote healthier eating.

Keywords: hunger; fruit familiarity, food intake, picky eating; food rejection.

INTRODUCTION

Sufficient fruit and vegetable (F/V) intake is crucial for healthy development, yet only a mere 17% of Dutch children meet the World Health Organization's (WHO) recommendation of five servings per day (Lynch et al., 2014). A survey of 1,279 Dutch parents revealed that just 21% of children aged 2-3 years, and almost none aged 4-6 years, meet the recommended vegetable intake (Ocké et al., 2008). These findings are consistent with trends observed in other countries (Kalmpourtzidou et al., 2020; McMath et al., 2023; Williams et al., 2020)

A common reason why this intake is so low is because children reject the food and refuse to eat it (Raggio & Gámbaro, 2018). This can be attributed to two types of food rejection, namely food neophobia and picky/selective eating (Lafraire et al., 2016; Rioux et al., 2018). Picky eating behavior and food neophobia often coexist, according to van den Brand et al. (2023). The difference between the two concepts lies in the novelty of the food. Food neophobia is the fear or strong aversion to trying new or unfamiliar foods. In contrast, picky eating behavior includes the rejection of both familiar and unfamiliar foods, for example, due to certain textures or other sensory characteristics (Rioux et al., 2017; Rioux et al., 2019). Therefore, picky eating is a broader concept that includes food neophobia, though some researchers or questionnaires distinguish them as separate behaviors

Sufficient healthy food intake begins with food acceptance, which is typically not a problem during a child's first year. However, between the ages of 2 and 4 years, children often begin to avoid unfamiliar foods and reject foods they previously liked (Jacobi et al., 2003). In the Netherlands, the prevalence of picky eating in 3-year-old children was found to be 27.6%, as determined using two eating-related measures from the Child Behavior Checklist (CBCL) (Cardona Cano et al., 2015).

Although most children eventually outgrow this phase of food rejection, individual differences can persist into adulthood. Research by Nicklaus et al. (2005) shows that young children who consume more fruit and vegetables tend to maintain healthier eating habits as they age. In the long term, the rejection of fruit and vegetables may increase the risk of chronic diseases such as obesity, cardiovascular diseases, and certain types of cancer (Chamoun et al., 2018).
It is therefore important that children establish a healthy diet at a young age.

To ensure children meet the recommended intake of fruit and vegetables, effective and easy-to-implement strategies are essential. Research shows that strategies like repeated exposure (Holley et al., 2017; Nekitsing et al., 2018) and offering children a choice can increase food acceptance, liking, and intake (Blanchette & Brug, 2005; Mourmans et al., 2023; Nekitsing et al., 2018). Another effective strategy could be offering children a new type of fruit or vegetable when they are hungry.

Studies have shown that hunger reduces the importance of taste (Ombrato & Phillips, 2021; Siep et al., 2009). The study by Siep et al. (2009) suggests that, when students are hungry, their brains may show increased activity in regions associated with food reward processing. So, hunger is proposed to enhance the rewarding value of food, particularly energy-dense foods, which could impact eating behavior. Additionally, several studies have examined the strategy of serving fruit and/or vegetables first during school lunches to increase intake among children (Elsbernd et al., 2016; Ferrante et al., 2019; Gibson & Wardle, 2001; Harnack et al., 2012; Ivy et al., 2022; Redden et al., 2015; Spill et al., 2010). This approach implicitly targets hunger, assuming children are hungriest at the start of lunch. These studies consistently found higher intake of fruit and/or vegetables compared to when not using this strategy. However, the studies often lacked a control

group of children who were not hungry and were only conducted with familiar F/V, often using carrots. The exception is the study by Gibson and Wardle (2001), which showed that presenting a novel fruit snack to a group of students, typically low in picky eating, who were hungry (having not eaten for 3 hours) compared to a group who were not hungry (having not eaten for less than 30 minutes), twice a day for one week, resulting in a higher intake for the hungry group compared to the non-hungry group.

Furthermore, another study examined the impact of hunger and fear on food neophobia by measuring the number of novel food items chosen compared to familiar ones in students (Pliner et al., 1995). Participants arrived either highly hungry (having been food-deprived for five or more hours) or less hungry (food-deprived for two hours or less) and were assigned to either give a speech (high fear) or listen to a speech (low fear). Then, all participants chose one item from each of ten pairs, each pair containing one novel and one familiar food. Results showed the least food neophobia when both fear and hunger were low. The study concluded that varying levels of drive to eat, either low or high, are created by the interplay of fear and hunger across different conditions, which in turn influences individuals' tendencies to choose between novel foods and familiar foods. Notably, hunger seemed to increase neophobic tendencies; however, this might especially apply when a familiar alternative is available (Pliner et al., 1995). This may be because a person knows that the familiar item can satisfy their hunger.

So, the precise influence of hunger on food acceptance, especially regarding unfamiliar foods remains unclear. This is especially important to explore in young children, as they tend to exhibit picky eating behaviors more frequently, and because establishing healthy eating habits early on is crucial, given that such behaviors often persist into adulthood. Therefore, the present study aims

to examine the role of hunger in the acceptance of an unfamiliar fruit compared to a familiar one. It is hypothesized that children in the hungry condition will show significantly higher food intake compared to children in the non-hungry condition. Additionally, we expect that children will demonstrate significantly higher food intake for a familiar fruit compared to an unfamiliar one. Furthermore, we predict that the impact of hunger on food intake will be significantly larger for a familiar fruit than for an unfamiliar one.

Additionally, the potential moderating role of picky eating is studied. The moderating role of picky eating in the present study is important as it may influence how hunger affects food acceptance. Picky eaters might be less responsive to hunger when it comes to trying familiar and unfamiliar foods, as their selective food preferences could outweigh their hunger drive. This interaction could reveal whether picky eating diminishes the impact of hunger on the willingness to try new foods. Therefore, it is expected that the effect of hunger will be moderated by children's levels of picky eating, such that the relationship between hunger and food intake will be significantly weaker for children showing more picky eating. Finally, it is also anticipated that children who exhibit more picky eating will show significantly less food intake for both an unfamiliar and a familiar fruit.

METHODS

Ethical approval

The Faculty of Psychology and Neuroscience at Maastricht University's Ethics Committee approved the present study (ERCPN-OZL-233-11-02-2021_S13). Prior to testing, parents submitted a written agreement for their child's participation. During testing, the child's decision not to participate was also respected. The study was preregistered on AsPredicted (157297) (https://aspredicted.org/

H9T_6D8), and analyses were carried out in accordance with the registered protocol.

Participants

The study was conducted at Dutch primary schools with children from groups 1 and 2 (aged 4-6). The sample size for this study was determined using G*Power 3.1 software, focusing on the analysis requiring the most statistical power (Faul et al., 2007). Based on calculations, a sample of 128 participants (32 in each group) was deemed necessary for a two-way ANCOVA (ANCOVA: fixed effects, main effects, and interactions) with an effect size of 0.25, alpha of 0.05, and a power of 0.80. To accommodate potential outliers, measurement errors, or weaker effects, our recruitment target was increased to 160 participants. Given the study's method to assess entire school classes and its alignment with another study, the actual number of participants exceeded this target. Children were eligible for participation if they understood either Dutch or English and were willing to join the experimenters when invited to take part in the study. Ultimately, 199 parents consented to their children's participation. However, 9 children were not tested due to illness and vacation, along with one parent who granted informed consent without filling out the questionnaires. Additionally, 13 children were later excluded from the analysis due to not following the instructions with regard to the hunger induction. The final sample comprised 177 children, including 91 boys and 86 girls aged between 4 and 6 years old (M = 4.70, SD = 0.64). The participating children attended primary schools in the South and Middle regions of the Netherlands, including different European backgrounds and varying social classes.

Study Design

The current study adopted a 2 x 2 between-subject design, wherein children were randomly allocated to one of four conditions: hunger (yes or no) x fruit familiarity (familiar/unfamiliar).

To induce hunger, teachers were instructed to omit the mid-morning snack or give it after testing, typically consisting of fruit or a cracker, from the children on the testing day in the hunger condition. In the hunger condition, children were assessed before lunch, resulting in approximately 4 hours of fasting. Conversely, in the no-hunger condition, children were tested within 20 minutes following lunch.

Based on the fruit familiarity condition, children were asked to either taste a familiar fruit, an apple, or an unfamiliar fruit, a lychee. These were chosen for their similar appearance when cut and their clear familiarity or unfamiliarity in the Netherlands. To verify the effectiveness of the manipulations, children were queried about their hunger levels (on a 3-point scale: yes/a little/no), familiarity with the fruit (on a 2-point scale: yes/no), and prior experience with tasting it (on a 2-point scale: yes/no). Additionally, before testing, parents were surveyed regarding their child's breakfast consumption habits and the usual time of breakfast. This information served to gauge "time since last meal," as children may struggle to accurately assess their hunger levels.

This study is an individual study, but most of the participating children also participated in another study conducted later in the same week on a different day. The dependent and independent variables of the two studies are different, except for the Child Food Rejection Scale (CFRS), which is utilized for both studies. Reference to the other study can be found on AsPredicted (157295) (https://aspredicted.org/QJS_B2S) and is named 'Investigating Shared Cognitive Traits in Autism Spectrum Disorder and Food Rejection'.

Procedure

The experimenters introduced themselves to the entire class and provided a brief explanation of the testing procedure. Children assigned to the hunger condition were informed that they would

be tested right before lunch, while those in the no-hunger condition were told they would be tested after lunch. To ensure that children in the hunger condition were actually hungry at the time of testing, they skipped their mid-morning snack. Instead, during the allocated snack time, these children were taken out of the classroom as a group to participate in short group activities with the experimenters. This arrangement prevented discomfort by ensuring they did not have to sit alongside classmates who were eating. After the snack break, they returned to the classroom, where the regular school program resumed. Testing took place individually in a quiet spot at the school. Children in the hunger condition were tested just before lunch, while those in the no-hunger condition were tested 20 minutes after lunch to allow time for digestion and to ensure the feeling of hunger had subsided (Figure 1).

The experiment began by asking the child about their current hunger level. Following this, questions regarding the child's familiarity with the fruit and prior experience tasting it were asked. These questions were accompanied by a visual aid, an image of either a familiar (apple) or an unfamiliar (lychee) fruit displayed as a whole and cut in half on an iPad.

Next, children were invited to taste the fruit depicted on the iPad. To ensure that the child knew what it was eating, a picture of a whole apple or lychee was still presented, allowing the child to identify the fruit being consumed. Children were shown a bowl with a total of nine pieces. After tasting one piece, children were asked if they desired additional pieces, with reassurance that the entire bowl containing nine pieces was available for their consumption. Tasting was completely voluntary, and children were allowed to refuse the fruit or spit it out if they did not want to swallow it. When the child indicated not wanting to continue eating, the experimenter informed the child that it was the end of the study. As a reward for participation, all

children received an eraser, after which the child was brought back to their classroom. The average duration of the study was around 5 minutes per child.

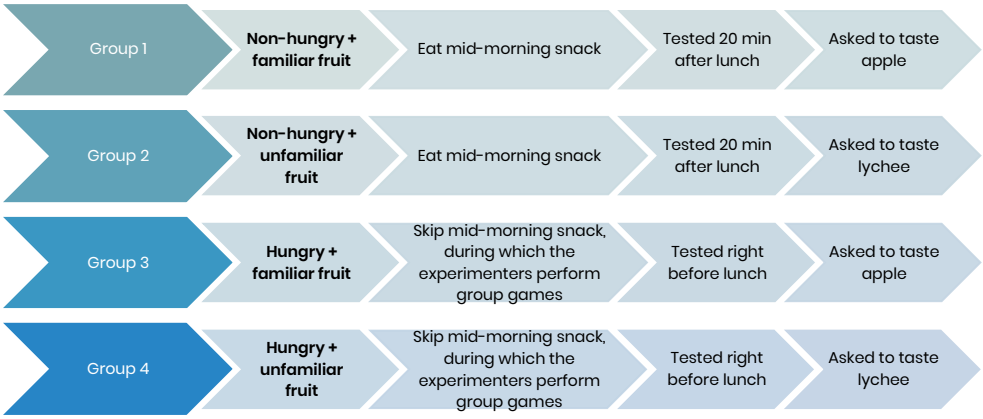


Figure 1. Visual diagram of the division of the groups (hunger and familiarity conditions).

Measurements

Demographic Variables

A parental questionnaire was used to collect certain demographic information: age (in years and months), gender (boy or girl), date of birth, and dietary restrictions.

Child Food Rejection Scale (CFRS)

Parents evaluated their child's food rejection using the Child Food Rejection Scale (CFRS) (Rioux et al., 2017). The CFRS comprises two subscales reflecting distinct food rejection dimensions: food neophobia (6 items) and pickiness (5 items). Caregivers assessed their agreement level with statements regarding their child's neophobia (e.g., "My child only prefers familiar foods") and pickiness (e.g., "My child refuses certain foods due to their texture"). Each item was rated on a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, 5 = strongly agree). The overall score ranged from 11 to 55, with higher scores indicating

heightened food rejection. Specifically, neophobia scores ranged from 6 to 30 (α = .87), while pickiness scores spanned from 5 to 25 (α = .69) (Rioux et al., 2017).

Food Intake

In each condition, children were invited to either taste a familiar (apple) or an unfamiliar (lychee) fruit. The child's food intake was measured using a 10-point scale, with higher scores indicating higher food intake for either the familiar or unfamiliar fruit. The scoring system ranged as follows: Score 0: corresponds to total refusal; Score 1: indicates some level of willingness to try the food, without swallowing the sample (e.g., touching, smelling, licking the food); Score 2: denotes consumption of a single piece; Score 3: signifies consumption of two pieces, and so forth, with the scale progressing up to (10) which corresponds to consumption of nine pieces. All pieces of the familiar and unfamiliar fruit were similar in size (1cm by 1cm).

Data analysis

Data were collected using Qualtrics on an iPad and analyzed using IBM SPSS (version 27.0, SPSS Inc, Chicago, IL). The data were initially screened for outliers using boxplots and descriptive statistics, with none identified. Descriptive statistics for all variables were then examined, and assumptions were verified. Gender and age were included as control variables in all analyses to account for their potential influence on the observed effects since gender and age have been associated with food preferences in previous research (Cooke & Wardle, 2005). To examine between-group differences, ANOVAs were conducted to compare between-group differences for continuous variables, such as age (in months) and CFRS scores. For categorical variables, including gender, hunger levels, fruit familiarity, and whether the fruit had been tasted before, chi-square tests were performed.

The analyses for the hypotheses were twofold. Firstly, to investigate the effect of hunger and fruit familiarity on food intake, a two-way ANOVA was conducted. Food intake served as the dependent variable, with hunger (yes/no) and fruit familiarity (familiar/unfamiliar) as fixed factors. Secondly, to examine the potential moderating effect of picky eating, a two-way ANCOVA was performed, incorporating the total Child Food Rejection Scale (CFRS) score as a covariate in the previous analysis. Additionally, as a secondary analysis, the correlation between food intake and picky eating (based on the CFRS) was examined.

RESULTS

Participant characteristics

The characteristics of the participants and the differences tested between groups are summarized in Table 1. A total of 177 children participated in the study, comprising 86 girls and 91 boys. The four groups were approximately equal in size following the exclusion of certain participants. Age and gender were evenly distributed across the four conditions. A chi-square test of independence revealed that children in the hungry condition reported significantly more feelings of hunger than those in the non-hungry condition, indicating the hunger manipulation was successful. Additionally, parental reports indicated an average time of 7:30 AM for breakfast, meaning children had not eaten for approximately 4 hours before the study. The apple was also found to be significantly more familiar and was consumed more frequently compared to the lychee, confirming the anticipated familiarity status of both fruits. Furthermore, picky eating scores did not significantly differ between conditions, as measured by the Child Food Rejection Scale (CFRS).

Table 1.

Participant Characteristics

	Experimental groups				
Characteristics	Not hungry, familiar	Not hungry, unfamiliar	Hungry, familiar	Hungry, unfamiliar	Tested group differences
N = 177	47	47	37	46	
Age (months)[a]	61.45 (6.60)	61.23 (6.61)	61.54 (7.80)	62.54 (7.62)	$F(3) = 1.60$, $p = .194$
Gender (girls/boys)[b]	24/23	21/26	23/14	18/23	$X^2 = 4.78$, $p = .191$
Question hunger levels (yes)[b]	7 (14.9%)	7 (14.9%)	26 (70.3%)	34 (73.9)	$X^2 = 69.39$, $p < .001$
Question familiarity (yes)[b]	47 (100%)	11(23.4%)	37 (100%)	9 (19.6%)	$X^2 = 112.14$, $p < .001$
Question tasted before (yes)[b]	46 (97.9%)	6 (12.8%)	37 (100%)	6 (13%)	$X^2 = 130.98$, $p < .001$
CFRS[c]	31.28 (7.76)	30.64 (6.84)	28.68 (7.52)	29.26 (7.45)	$F(3) = 1.13$, $p = .340$

[a] Mean values, (standard deviations) per group

[b] Number of participants answering 'yes', (percentages) per group

[c] Scores of the Child Food Rejection Scale, (standard deviation) per group

The effect of hunger and fruit familiarity on food intake

A two-way ANOVA investigated the effect of hunger and fruit familiarity on food intake. The results are presented in Figure 2. As hypothesized, there was a significant main effect of hunger ($F(1, 174) = 9.73$, $p = .002$), indicating that children in the hungry condition consumed more fruit overall, regardless of the type (apple or lychee), than children in the non-hungry condition.

The main effect of the familiarity condition was statistically significant ($F(1, 174) = 40.09$, $p \leq .001$). As hypothesized, children exhibited significantly higher food intake for the familiar fruit (apple) compared to the unfamiliar fruit (lychee). The interaction effect between hunger and fruit familiarity was found to be non-significant ($F(1, 173) = 0.01$, $p = .94$). So, hunger did not significantly alter the impact of fruit familiarity on food intake.

For transparency, we conducted a sensitivity analysis by excluding children who did not fully align with their assigned conditions. Removing these children had minimal impact on the results: the F-value for the main effect of hunger changed from 9.73 to 9.58 (a change of 0.15), and the F-value for the main effect of familiarity changed from 40.09 to 39.85 (a change of 0.24), demonstrating the robustness of our findings. As such, the full sample was retained for the final analyses.

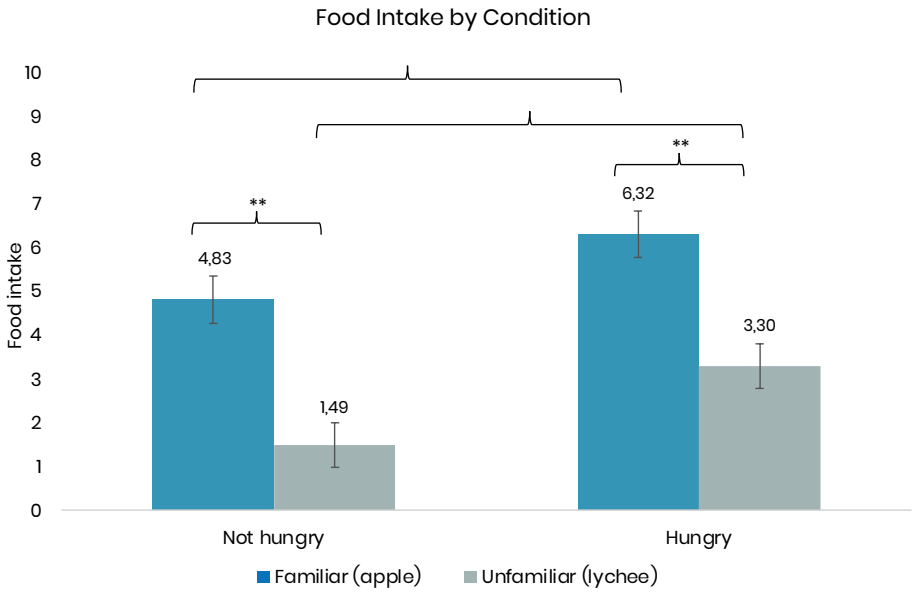


Figure 2. Visual presentation of the mean food intake by condition and standard error. The main effects of the hunger and fruit familiarity conditions are significant. The interaction effect between hunger and fruit familiarity is not significant. p* < 0.005, p** < 0.001.

Moderating effect of picky eating on food intake

The CFRS score was included as a covariate in the 2 x 2 ANCOVA analysis. The analysis showed that the main effect of picky eating on food intake was not significant ($F(1, 173) = 2.42$, $p = .12$). In addition, the interaction between picky eating and hunger ($F(1, 176) = 1.29$, $p = .26$), between picky eating and familiarity ($F(1, 176) = 0.07$, $p = .79$), and the

three-way interaction between picky eating, hunger, and familiarity were all not significant ($F(1, 176) = 0.06$, $p = .81$).
Secondary analyses were conducted to explore the correlations (Pearson) between picky eating (total CFRS score) and food intake, specifically focusing on the subscales' food neophobia and food pickiness. Neither correlations were found to be significant ($r(175) = 0.09$, $p = .26$; $r(173) = 0.06$, $p = .46$, respectively). Furthermore, the correlation between picky eating (total CFRS score) and food intake for the unfamiliar fruit (lychee) was not significant ($r(95) = 0.09$, $p = .41$). This was not as expected because unfamiliar food is rejected more often. The correlation between the picky eating (total CFRS score) and food intake for the familiar fruit (apple) only was also not significant ($r(96) = 0.08$, $p = .30$).

DISCUSSION

The primary objective of the present study was to investigate how hunger influences the willingness of children aged 4-6 years to accept an unfamiliar fruit compared to a familiar one. Additionally, the study examined how picky eating moderated this effect. To explore these aspects, the study employed conditions of hunger and fruit familiarity. The hungry group of children, who had not eaten for 3 to 4 hours, was tested before lunch, whereas the non-hungry group, who had eaten less than 30 minutes prior, was tested after lunch. The familiar fruit was an apple, and the unfamiliar fruit was a lychee. Children could choose to eat up to nine pieces of fruit or reject them entirely, which is the measure of food intake. Additionally, parents completed the CFRS questionnaire to assess their child's food rejection tendencies, including food neophobia and pickiness.

As anticipated, hungry children ate more of both the familiar and unfamiliar fruits compared to the non-hungry children. Consistent with our expectations, children also ate more of the familiar fruit

than the unfamiliar fruit. However, we did not find that hunger had a greater impact on the intake of familiar fruit compared to unfamiliar fruit. Instead, hunger equally influenced the intake of both types of fruit, leading to an overall increase in food consumption. Therefore, these results suggest that giving a child a novel or familiar fruit when hungry is a valuable strategy for higher intake. To our knowledge, this is the first study to compare the effects of hunger on children's willingness to eat familiar versus unfamiliar fruits. Our findings align with previous research showing that offering fruit or vegetables to children at the beginning of school lunches leads to higher intake (Elsbernd et al., 2016; Ferrante et al., 2019; Gibson & Wardle, 2001; Harnack et al., 2012; Ivy et al., 2022; Redden et al., 2015; Spill et al., 2010). Related studies further support our findings, indicating that taste matters less when someone is hungry (Ombrato & Phillips, 2021; Siep et al., 2009). Notably, this effect has primarily been found with energy-dense foods, but our results suggest it also applies to less energy-dense options. So, when a child is hungry, they may be more inclined to try and eat an unfamiliar fruit, even if they do not know how it tastes. These studies reinforce the idea that hunger can increase the acceptance of both familiar and unfamiliar foods, aligning with our results.

Contrary to our expectations, there was no significant relationship between food intake (for both the familiar and unfamiliar fruit) and picky eating based on the parental questionnaire (CFRS). Even when examining only the intake of unfamiliar fruit, no significant relationship was detected, despite the fact that picky eating is often associated with a reluctance to try unfamiliar foods. Furthermore, picky eating did not moderate the effect of hunger and familiarity on food intake. This suggests that, regardless of their tendency to reject foods, there are no indications that the hunger manipulation is ineffective for picky eaters, even when the food is unfamiliar. The lack of evidence for a relationship between children's fruit intake

and their picky eating, as assessed by a parental questionnaire, suggests potential discrepancies between parental perceptions and children's actual behavior during the task. These differences might arise from various contextual factors, such as the home versus school environment, parental (mis)interpretation of their child's behavior, or the child's comfort level in the research setting. For example, children's fruit intake could have been influenced by a desire to please the researcher or shyness, potentially leading to variations in consumption. Parental responses to the CFRS may also have been affected by memory and recall biases, resulting in over- or underestimation of the child's food rejection tendencies (Alley, 2018; Lee et al., 2022). Consequently, parental and child measures may each have distinct sources of error, leading to a weaker correlation between these types of assessments. Further research should explore more reliable methods for comparing child consumption tasks and parental reports.

The current study has several strengths. This study stands out due to its large sample size and experimental design. It includes a comparison group of non-hungry children and examines the intake of a familiar compared to an unfamiliar fruit—areas where previous studies have often lacked such comparisons. Another strength of the study is that children were not limited to either rejecting the food or eating just one piece; they could consume as many pieces as they wanted, up to a maximum of nine. This approach demonstrates ad libitum feeding, allowing children to eat freely within the set limit, and shows more variability.

However, some limitations should be considered. It is worth noting that this study focuses solely on fruit, which are generally more palatable for children compared to vegetables, yet are still often rejected by picky eaters. Thus, while the study shows that hunger influences fruit intake, its findings may not apply to other nutritious foods. Future research should explore different food categories, including vegetables, to

broaden our understanding and generalizability. Further, the study was a between-subjects design. Although the groups did not significantly differ in terms of age and sex, it is impossible to know if the groups differed in some unmeasured factors that could have affected the results. Future studies might consider using a within-subjects design to investigate whether hunger and familiarity affect intake similarly within individuals. Additionally, the testing times varied slightly between the hunger conditions. However, since neither session took place during a regular snack time, any impact on intake is likely minimal. Furthermore, using piece counts instead of weight measurements may have introduced some imprecision, though this effect was likely negligible due to the consistent piece size. Moreover, this study only examines the short-term effect of hunger on food intake. It remains unclear whether children are more likely to try the fruit again after initially tasting it while hungry. Further research should explore if children who try unfamiliar fruit when hungry are more likely to accept it in the future, as one would expect according to the mere exposure effect (Anzman-Frasca & Ehrenberg, 2018). This could provide valuable insights into the long-term effects on food preferences. Finally, this study did not include a clinical sample of children diagnosed with conditions such as Avoidant/Restrictive Food Intake Disorder (ARFID) (Zimmerman & Fisher, 2017). While this study shows that hunger promotes food intake in children with varying levels of picky eating, the effect might be different when children exceed a certain threshold of problematic eating. Future research should therefore incorporate clinical samples to validate the effect of hunger on food intake in these populations.

Offering children new or familiar fruits when they are hungry seems to be an effective way to encourage them to try these fruits, serving as an initial step toward increasing fruit consumption. This approach can be combined with the well-established strategy of repeated exposure, which has been shown to enhance food intake

and acceptance of new foods in young children (Anzman-Frasca & Ehrenberg, 2018; Anzman-Frasca et al., 2018; Cooke, 2007). Children tend to prefer foods they are familiar with and are more likely to eat what they prefer. Introducing a novel fruit through several tastings can make it more familiar and thus more preferred. Aldridge et al. (2009) found that much of the variation in food preferences in children was due to their level of familiarity with the food. However, getting children to try a new food can be challenging, especially since young children often refuse certain foods upon sight, including fruits. Therefore, future research could explore combined strategies, starting with using mild hunger to encourage initial acceptance of new foods, followed by repeated exposure to increase familiarity. Once a child has tried a new food item, repeated tasting could help increase their fruit intake to meet daily recommendations. Additionally, the finding that hunger did not appear ineffective regardless of children's level of picky eating is encouraging, as it suggests that even picky and neophobic children might be more willing to try new (or familiar) fruit when hungry.

In conclusion, the present study demonstrated that children are more willing to eat a familiar and an unfamiliar fruit when hungry. Furthermore, children's picky eating (based on a parental questionnaire) does not seem to diminish the influence of hunger on their food intake of either type of fruit. Therefore, offering children fruit, whether new or familiar, when they are hungry can effectively enhance their fruit consumption. This approach can be easily adopted by parents and educators to encourage healthier eating habits, potentially in combination with the method of repeated exposure.

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Chapter 6

The Influence of Positive Reinforcement, Negative Reinforcement and Exposure on Children's Food Intake and Liking

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ABSTRACT

Young children often consume too few fruit and vegetables, partly due to picky eating. While repeated exposure can improve acceptance, the added value of reinforcement strategies remains unclear. This pre-registered within-subject study investigated whether combining exposure with positive or negative reinforcement (using non-food rewards) enhances intake and liking of unfamiliar vegetables compared to exposure alone or a control condition. Sixty-two children aged 4–6 years participated in a 10-day school-based intervention involving all four conditions: positive reinforcement (tasting earned a cartoon card), negative reinforcement (tasting prevented card loss), exposure (tasting without rewards), and a control condition. Intake and liking of four unfamiliar vegetables (purple carrot, yellow beetroot, blue meat radish, and rutabaga) were measured on days 1 and 10, with intake also recorded during the intervention (days 2–9). Conditions and vegetable order were counterbalanced. The potential influences of reward sensitivity (RS) and punishment sensitivity (PS), and picky eating were also examined. Results from repeated-measures ANOVAs showed that positive reinforcement led to the highest post-intervention intake, followed by negative reinforcement, exposure, and control, with significant differences between all conditions. For liking, only positive reinforcement showed a significant improvement over the other conditions. RS and PS did not moderate outcomes, but higher picky eating was associated with lower intake and liking across all conditions. In conclusion, adding positive reinforcement to exposure most effectively increases young children's intake and liking of unfamiliar vegetables. This low-cost, easily implementable strategy can support parents and educators in promoting healthier eating habits in early childhood.

Keywords: reinforcement strategies; exposure; food intake; food liking; picky eating; unfamiliar vegetables.

INTRODUCTION

A major challenge in promoting healthy eating among children is encouraging the intake and liking of fruit and vegetables, especially fruit and vegetables that are unfamiliar. In the Netherlands, the vast majority of children do not meet the World Health Organization's (WHO) recommendation of consuming at least five servings of fruit and vegetables per day (Lynch et al., 2014; Van Rossum et al., 2020), a pattern that is similarly observed across various other countries (Kalmpourtzidou et al., 2020; McMath et al., 2023; Williams et al., 2020). In the short term, inadequate intake can lead to nutritional deficiencies that hinder healthy growth and development. Over the long term, insufficient consumption of fruit and vegetables is associated with an increased risk of non-communicable diseases, including obesity and cardiovascular conditions (Chamoun et al., 2018).

Low fruit and vegetable intake in childhood is often attributed to picky eating, which involves the rejection of a wide variety of foods (Raggio & Gámbaro, 2018). A specific aspect of picky eating is food neophobia, the reluctance to try unfamiliar foods (van den Brand et al., 2023). Although picky eating is generally considered a normal part of early childhood development, persistent food rejection during this period can lead to long-term unhealthy dietary habits and limited food preferences (Mikkilä et al., 2004). Food preferences begin to develop early in life, often by the age of two to three years, and tend to remain relatively stable over time (Birch & Anzman, 2010; Skinner, Carruth, Bounds, & Ziegler, 2002). These early preferences are known to influence eating habits later in childhood and even into adulthood (Skinner, Carruth, Bounds, Ziegler, et al., 2002). Importantly, young children who consume more fruit and vegetables tend to maintain healthier eating habits as they age (Kemp et al., 2025; Nicklaus et al., 2005). Since children are more likely to consume foods they know and enjoy, their dietary intake is closely linked to their individual likes

and dislikes (Keller et al., 2022). Encouraging exposure to a variety of foods early in life is, therefore, key to fostering lasting healthy eating habits.

Childhood is a key period in which dietary habits are formed, making it a suitable time for interventions that promote vegetable consumption. It is therefore important to explore ways to increase children's acceptance and liking of vegetables and reduce picky eating, especially of unfamiliar vegetables. One well-established method to increase children's acceptance of unfamiliar foods is repeated exposure (preferably to taste) (Nekitsing, Hetherington, et al., 2018). Research consistently shows that the more often children are exposed to a new food, the more likely they are to develop a preference for it. An early study showed that food preference grows as a function of exposure frequency (Birch & Marlin, 1982). The consensus is that repeated exposure helps familiarize children with novel foods, such as vegetables, reducing their initial neophobic (fear or reluctance) response and increasing acceptance over time, likely through psychobiological mechanisms such as sensory habituation and reduced uncertainty toward the novel food (Caton et al., 2013; Mura Paroche et al., 2017). This strategy has since been widely supported in the literature as an effective way to improve children's acceptance of unfamiliar vegetables (Caton et al., 2013; de Wild et al., 2015; de Wild et al., 2013; Lakkakula et al., 2010). Evidence suggests that at least 8 to 10 tasting opportunities may be needed to increase not only liking but also actual consumption of vegetables (Barends et al., 2019; Nekitsing, Blundell-Birtill, et al., 2018; Spill et al., 2019). Despite its effectiveness, many parents are unaware of this method or find it challenging to repeatedly offer vegetables that their children initially dislike, often perceiving it as a frustrating or burdensome task (Houston-Price et al., 2019).

While repeated exposure is a well-established strategy for increasing acceptance and liking of vegetables, research suggests that other mechanisms might be used in conjunction with repeated exposure to yield even greater effects. One such strategy is the use of non-food rewards, which has been shown in several studies to enhance the effectiveness of repeated exposure in encouraging children to eat more vegetables. This technique is a form of positive reinforcement, where a reward is given to encourage the desired behavior. For example, a study by van Belkom et al. (2023) found that a reward-based contingency management program was more effective than repeated exposure alone in increasing toddlers' vegetable acceptance in day-care settings. Notably, this effect could not be explained solely by increased familiarity with the vegetables, suggesting that the reinforcement itself played a critical role. Furthermore, Cooke et al. (2011) found that 4–6-year-old children who received tangible rewards for tasting vegetables showed a significant increase in intake compared to children who only experienced repeated exposure. This improvement in vegetable consumption was maintained even after three months. Comparable results were found by Remington et al. (2012), who reported that combining exposure with a tangible reward led to significantly greater intake and liking of a moderately disliked vegetable among children aged 3 to 4 years compared to a non-treatment control condition. This effect was stronger than that of exposure paired with a social reward or the control condition. Notably, these improvements in both intake and liking were maintained at a 3-month follow-up. Similar effects have been observed by Fildes et al. (2014), who studied a program where parents combined exposure with sticker rewards in 3– to 4-year-olds, resulting in increased acceptance, both in terms of intake and liking, of a previously disliked vegetable. However, because the study lacked a control group with exposure alone, it remains uncertain whether the effect can be explained by rewards, exposure, or a combination of both. In contrast, a study by de Gooijer

et al. (2024) found that while combining exposure with reward and additional storytelling did increase children's willingness to taste both liked and disliked vegetables, it did not significantly enhance actual intake or liking. Moreover, other studies indicate that although combining exposure with rewards does not improve intake, liking, or willingness to taste beyond exposure alone, both approaches are still more effective than no intervention at all (Vandeweghe et al., 2018; Wardle et al., 2003). However, the effects of rewards on intake and liking of unfamiliar vegetables have not yet been studied. Examining unfamiliar vegetables is important, as these foods typically elicit stronger neophobic reactions, and children's willingness to try them is important for developing a varied and healthy diet (Dovey et al., 2008; Laureati et al., 2015).

Although several studies have examined the effects of positive reinforcement, negative reinforcement is also a potential strategy to increase food acceptance, one that appears to be used by parents (Grieshaber, 1997), but its effectiveness has not yet been established. Negative reinforcement, which involves encouraging a desired behavior (e.g., eating an unfamiliar vegetable) by removing or avoiding an unpleasant consequence, may also influence children's eating behavior. A specific form of negative reinforcement is avoidance learning, where behavior is encouraged by the opportunity to prevent a future negative consequence. For example, a child might need to eat a certain food in order to avoid doing the dishes or losing screentime (Mazur, 2016). Although this approach may increase short-term compliance, controlling and avoidance-based strategies may undermine autonomy and intrinsic motivation and hinder the development of positive affective associations with food (Deci & Ryan, 2000; Galloway et al., 2006). Some research indicates that parents use negative reinforcement during mealtimes (Grieshaber, 1997; Pelchat & Pliner, 1986), yet its direct effects on children's acceptance and liking of unfamiliar foods remain largely unexplored. A related

study on memories of parental food rules suggests that using food as a means to control behavior can have long-term effects on eating patterns in adulthood. These "control rules" included denying dessert, cleaning your plate after each meal, or withholding favorite foods. Adults who recalled such rules more frequently reported higher levels of binge eating, greater dietary restraint, and a higher BMI (Puhl & Schwartz, 2003). However, the effects of negative reinforcement are not inherently negative. In another context, negative reinforcement has been shown to be effective in decreasing problem behavior in children with behavioral disorders. Removing an aversive task after desired behavior increased the frequency of that behavior (Athens & Vollmer, 2010). These findings raise important questions about how negative reinforcement applied in feeding contexts may impact children's acceptance and liking of (unfamiliar) foods. Notably, the studies described above all employed avoidance learning.

Probably, how children respond to reinforcement strategies may depend on how sensitive they are to rewards or punishments. Reward sensitivity (RS) and punishment sensitivity (PS) are temperamental traits that reflect how strongly children react to positive or aversive stimuli. RS is associated with the behavioral approach system (BAS), which drives approach behavior in response to rewarding stimuli. In contrast, punishment sensitivity is related to the behavioral inhibition system (BIS), which is activated by signals of punishment or threat and results in avoidance or inhibition of behavior (Gray, 1987). A parent questionnaire-based study showed that children with higher RS are more likely to show food approach behavior, while children with higher punishment sensitivity are more likely to exhibit food avoidance behavior (Vandeweghe, Vervoort, et al., 2016). Furthermore, children high in RS were more likely to taste immediately when rewarded, while children low in RS were more willing to taste when verbally encouraged, but with hesitation (Vandeweghe, Verbeken, et al., 2016). Based on these studies, it is plausible that children high

in RS may respond more strongly to positive reinforcement, which involves adding a rewarding stimulus to encourage behavior. Similarly, children high in punishment sensitivity might be more responsive to negative reinforcement, which involves strengthening behavior through the removal or avoidance of aversive outcomes, including negatively framed consequences such as the threat of losing a reward. Although negative reinforcement is conceptually distinct from punishment, children who are sensitive to negative stimuli or framing (i.e., punishment-sensitive in a broader sense) may be more driven to engage in behaviors that lead to the reduction or removal of such negative input (Corr, 2004; Gray, 1982; Kazdin, 2012). In this way, their punishment sensitivity may translate into a greater responsiveness to negative reinforcement, which functions by taking away something unpleasant. However, there is currently little direct empirical evidence examining whether these individual differences influence reinforcement strategies in shaping children's eating behavior.

Despite the promising findings on adding reinforcement to repeated exposure, there is still limited research on how positive and negative reinforcement strategies influence children's intake and liking of unfamiliar vegetables. Previous studies have mainly focused on familiar or already disliked foods, whereas it remains unclear whether reinforcement also enhances acceptance of unfamiliar vegetables that often elicit stronger neophobic reactions. Moreover, while positive reinforcement has been studied, negative reinforcement has not yet been experimentally tested in this context. The present study, therefore, provides a novel contribution by directly comparing both positive and negative reinforcement to repeated exposure and a control condition. Specifically, we examined whether pairing tasting behavior with the opportunity to gain a reward (positive reinforcement) or keep/avoid losing a reward (negative reinforcement) enhances children's intake and liking of unfamiliar

vegetables. more effectively than repeated exposure without reinforcement or a control condition without repeated exposure. In addition, we explored whether these effects interact with individual differences in children's reward and punishment sensitivity.

It was hypothesized that children would show the highest levels of vegetable intake after exposure in the positive reinforcement condition, followed by the negative reinforcement condition, then the exposure condition, and finally the control condition. Positive reinforcement was expected to be most effective due to its ability to create motivational incentives, while negative reinforcement may still encourage tasting but with reduced effectiveness due to its aversive framing. Repeated exposure was expected to promote moderate increases through familiarity, and the control condition was expected to result in no or minimal changes in intake. With regard to liking, we also expected the most favorable outcomes in the positive reinforcement condition, followed by the exposure condition, the negative reinforcement condition, and finally the control condition. It was hypothesized that positive reinforcement would not only promote tasting but also enhance the hedonic experience by associating the vegetable with a rewarding outcome. Repeated exposure without reinforcement was also expected to increase liking through familiarity. In contrast, the negative framing of the negative reinforcement condition may hinder the development of positive associations, and minimal exposure in the control condition is unlikely to affect liking.

In addition to these main effects, it was explored how reward and punishment sensitivity moderate the effectiveness of reinforcement strategies. It was expected to influence the responsiveness to the conditions. Specifically, children who are more sensitive to reward are expected to respond more strongly to the positive reinforcement condition, while those with higher punishment sensitivity may comply

more in the negative reinforcement condition. Finally, the role of picky eating was examined. Children with higher levels of picky eating were expected to exhibit lower levels of vegetable intake and liking across all conditions. Whether the effectiveness of the interventions is moderated by the degree of food picky eating was also explored.

METHODS

Ethical approval and preregistration

The study received ethical approval from the Ethics Committee of the Faculty of Psychology and Neuroscience at Maastricht University (reference: ERCPN-OZL-233-11-02-2021_S15). Parental written consent was obtained before children were allowed to participate. Additionally, children's decisions were respected at all times, and they were free to withdraw from the study at any stage. The study was preregistered on AsPredicted (210427) at https://aspredicted.org/see_one.php, and all analyses adhered to the preregistered protocol.

Participants

Data were collected from children aged 4 to 6 years, attending primary school classes 1 and 2 in the south of the Netherlands. After contacting several schools, two schools agreed to participate. Across these schools, all 200 children in groups 1 and 2 were invited to participate, of whom 62 ultimately participated (response rate = 31%). Children were eligible to participate if they understood either Dutch or English. They were included in the final analyses if they completed at least 6 out of 8 intervention sessions (excluding the pre- and post-measurements). In total, 62 parents provided written consent for their child's participation, resulting in a sample of 62 children (27 boys and 35 girls) aged between 4 and 6 years (M = 4.68, SD = 0.70). All 62 children completed the pre-measurement and at least six intervention sessions. However, four children were absent on the day of the post-measurement, resulting in a final sample of 58

children for the main (pre- and post-measurement) analyses.

To determine the required sample size, G*Power (Faul et al., 2007) was used, focusing on the analysis requiring the greatest statistical power. Since G*Power does not support sample size calculations for repeated measures ANCOVA with a continuous covariate, the covariate was dichotomized for this estimation. This approach resulted in a conservative overestimation of the required sample size, as the actual analyses used the covariate in its continuous form. Using G*Power, it was estimated that 36 participants would be needed to detect a within-between interaction in a repeated measures ANCOVA, assuming an effect size of 0.20, an alpha level of 0.05, and a power of 0.95. This calculation was based on eight total measurements per participant, two time points (pre- and post-measurement) across four experimental conditions. Additionally, an alternative approach using a power plot was explored, illustrating the required sample size across a range of effect sizes from small to medium. Based on this analysis, a sample size between 50 and 100 participants would be appropriate. Therefore, we aimed to recruit approximately 70 children through parental consent, acknowledging that recruitment via classrooms could result in a slightly higher or lower final sample size.

Study Design

This study used a 10-day within-subjects design (spanning two school weeks, excluding weekends) to examine the effects of positive reinforcement, negative reinforcement, repeated exposure, and a control condition on children's intake and liking of unfamiliar vegetables. Each child was introduced to four unfamiliar vegetables (purple carrot, yellow beetroot, blue meat radish, and rutabaga), each of which was paired with a specific experimental condition that stayed the same for that child across the whole study. The assignment of vegetables to conditions, as well as the order of their

presentation, was systematically randomized and counterbalanced across participants using a Latin square design (see Supplementary Materials, Tables S1–S2, for a full overview of the randomization).

On day 1 (pre-measurement) and day 10 (post-measurement), all four vegetables were presented one at a time, with children rating their liking immediately after tasting each vegetable. During the pre-and post-measurement, children could taste up to three small pieces per vegetable. Children were asked twice to eat the vegetable, and if they refused both times, the experimenter moved on. The control condition was only included during these pre- and post-measurements and did not feature in the intervention sessions. So, the vegetable assigned to the control condition was left out during the intervention sessions.

The intervention sessions took place from day 2 to day 9 and included only the three active experimental conditions: positive reinforcement, negative reinforcement, and repeated exposure. On day 2, all children received ten cartoon cards along with a personal book to store them. There were 8 additional cards to win, adding up to 18 cards in total. Children who ate all their assigned vegetables earned all the cards by the final day, while those who did not eat anything still kept at least two cards at the end of the testing period. During the intervention sessions, children were offered one piece of the assigned vegetable per condition per day, and only their intake was recorded; liking was not measured. In the positive reinforcement condition, children could earn an extra card by tasting the vegetable, with no penalty for refusal (e.g., "If you eat this vegetable, you can choose an additional card"). In the negative reinforcement condition, children risked losing a card if they refused to taste the vegetable, but could keep all their cards if they did taste it (e.g., "If you eat this vegetable, you keep your cards and won't lose any"). For ethical reasons and to diminish negative feelings, children were allowed to

choose which card to give up if they refused. To keep the card loss meaningful and prevent children from giving up cards they did not care about, they were reminded several times that the goal was to collect all the cards for a larger reward. This reward, a vegetable-themed keychain, was identical for all children and was only given after the post-measurement to ensure it did not influence children's responses during the final assessment. In the exposure condition, children were simply invited to taste the vegetable without any cards being gained or lost (e.g., "Do you want to eat this vegetable?").

Measurements

Demographic Variables

Parents/caregivers completed several questionnaires, including demographic questions, items regarding the test foods used in the study, and the Child Food Rejection Scale (CFRS). They received these questionnaires along with an information letter and informed consent form. As part of the demographic section, they were asked to provide details such as their child's age, gender, date of birth, and any dietary restrictions.

Test Food Familiarity

Parents were asked about seven relatively unfamiliar vegetables, although only four of these vegetables (purple carrot, yellow beetroot, blue meat radish, and rutabaga) were actually used in the study. The additional three vegetables (parsnip, celeriac, and okra) were included to reduce the likelihood that parents would discuss specific vegetables with their children beforehand. For each of the seven vegetables, parents answered two questions. First, they indicated how often the child had been offered the vegetable, using a 6-point scale (1 = rarely or never, 2 = once a month, 3 = once a week, 4 = 2–3 times per week, 5 = 4–6 times per week, 6 = daily or more). Second, they were asked whether the child liked the vegetable ('yes' or 'no'). If the child had never tried it before, parents could respond

with 'probably yes' or 'probably no'. All responses were coded into a 4-point scale: 1 = no, 2 = probably not, 3 = probably yes, 4 = yes. These two questions were used as a baseline check to ensure that the vegetables included in the study were offered with similar frequency and liked to a comparable degree, minimizing the risk that outcome differences could be explained by prior exposure or preferences (please note that the allocation of vegetables to conditions was balanced, thereby also preventing that prior exposure and preferences influenced the outcomes).

Food Intake and Liking

The main outcome variables in this study were food intake and food liking, which were assessed during both the pre- and post-intervention phases. A modified version of the scale by Blissett et al. (2016) was used to measure food intake on a 5-point scale: (1) physical and verbal refusal, (2) some willingness to try without swallowing (e.g., touching, smelling, or licking the food), (3) one piece eaten, (4) two pieces eaten, and (5) three pieces eaten. If a child ate a partial piece of the vegetable, it was scored as one piece eaten. Food liking was measured using a child-friendly 4-point smiley face scale ranging from 'dislike very much' to 'like very much', designed to be easily interpreted by young children and to avoid a neutral response. Children were asked, "How much do you like this vegetable?", and could either point to the corresponding smiley or verbally indicate their response (Mourmans et al., 2023). During the intervention phase, only food intake was recorded, using a simplified 3-point scale: (1) physical and verbal refusal, (2) some willingness to try without swallowing, and (3) one piece eaten. The pre- and post-assessment scale was set at a maximum of three pieces eaten to minimize the risk of a ceiling effect and allow for the detection of changes in intake over time.

Child Gambling Task

The Child Gambling Task (CGT) (Kerr & Zelazo, 2004) was used to measure the child's sensitivity to reward and punishment. This task was an age-appropriate version of the Iowa Gambling Task (IGT) and examined decision-making in the context of uncertain rewards and losses. In the study by Kerr and Zelazo (2004) the CGT was used with physical cards, but in the current study it was digitalized. The CGT consisted of two card decks: one advantageous and one disadvantageous. The backs of the cards were randomly marked with either dots or stripes, but these markings did not correspond to the value of the deck. When a child selected a card, it was revealed, and the number of happy and sad faces on the card indicated how many coins they would gain or lose. Cards from the advantageous deck always included one happy face and either zero or one sad face, resulting in small but consistent gains over time. In contrast, cards from the disadvantageous deck always showed two happy faces, but could also display zero, four, five, or six sad faces, leading to larger immediate gains but long-term losses (see Figure 1 for an example). Children were instructed to collect as many coins as possible over 50 trials, which usually took between five and ten minutes. The first six trials served as a demonstration, during which children selected each deck three times while the meanings of the revealed cards and their impact on the overall coin total were explained. As a result, every child began the task with a starting balance of four coins. Throughout the task, the number of coins earned was displayed below the two card decks on the iPad screen. Children were free to choose from which deck to draw on each trial. Prior to starting, children were told that the more coins they collected, the bigger the present they would be able to choose at the end of the task. However, for ethical reasons, all children were ultimately allowed to select from the full range of prizes (i.e., sticker, stamp, or a small stuffed animal), regardless of their final coin total. The primary outcome measure was the choice of deck. Selections from the advantageous deck were scored as 0,

and selections from the disadvantageous deck as 1. Scores could range from 0 to 50. Higher scores reflected greater RS and lower PS. Lower scores reflected lower RS and higher PS. This measure was used in further analyses to examine how individual differences in sensitivity to reward and punishment related to children's responses in the different conditions.

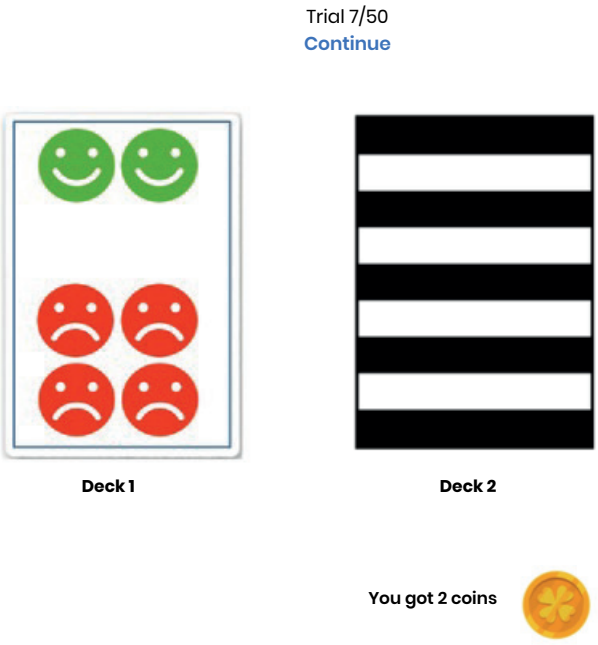


Figure 1. Example of the CGT with a choice from the disadvantageous deck

Child Food Rejection Scale (CFRS)

To measure picky eating in children, caregivers completed the Dutch translated version of the Child Food Rejection Scale (CFRS) (Hendriks-Hartensveld et al., 2023; Rioux et al., 2017). This questionnaire included two subscales: food neophobia (6 items) and picky eating (5 items). Caregivers rated how much they agreed with statements about their child's eating behavior, such as a preference for familiar foods (neophobia) or avoidance based on texture (picky eating), using a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The combined scale yielded a total score from 11 to 55, with

higher values reflecting greater picky eating. In the current study, the internal consistency was high across all items (α = .85).

Procedure

Before the start of the study, when a school agreed to participate, the researcher distributed envelopes to all children who could participate. Teachers handed the envelopes to the children, containing an information letter, consent form, CFRS questionnaire, and test food familiarity form. Parents who consented completed the forms and returned them via their child to the teacher, who collected all completed forms. Only children whose parents provided consent participated in the study.

On day 1, a pre-measurement was conducted in which children could taste up to three small pieces of each of the four unfamiliar vegetables. Both intake and liking were assessed to establish baseline measures. In addition, the CGT was administered at the end to measure each child's sensitivity to reward and punishment.

From day 2 to day 9, children participated in daily card-based intervention sessions. Each day, they went through the three active experimental conditions: positive reinforcement, negative reinforcement, and repeated exposure. For each condition, the child was offered one piece of the specific vegetable associated with that condition. The vegetable-condition pairings and the daily order of conditions were kept consistent for each child but were counterbalanced across participants to control for order effects and vegetable preferences. During these sessions, children collected cartoon cards in a personal card book, with the opportunity to gain, lose, or keep cards depending on their tasting behavior and the condition-specific rules. Only intake was recorded during these sessions; liking was not measured.

On day 10, children completed the post-measurement, again tasting up to three small pieces of each of the four vegetables, including the one assigned to the control condition. Intake and liking were reassessed to evaluate changes compared to baseline.

Children received small incentives during the study, including a gift (i.e., stickers or a stamp) after completing the CGT, their personal card book, and an additional gift at the end. No incentives were provided to parents.

Data analysis

The data were analyzed using Jamovi (The Jamovi Project, 2024). The study used a within-subjects design with two within-subject factors: (1) ***condition*** with four levels (positive reinforcement, negative reinforcement, exposure, and control), and (2) ***time*** with two measurement points (pre- and post-intervention). To assess changes in intake and liking across these conditions, two separate repeated measures General Linear Models (GLMs) were conducted, one for intake and one for liking. Additionally, to explore how intake developed over time during the intervention sessions, a repeated measures ANOVA with a 3 × 8 design was carried out. This analysis included the three active conditions (positive reinforcement, negative reinforcement, and exposure) across the eight intervention days (days 2 to 9). To perform this timeline analysis, a complete dataset was required. Therefore, 138 missing values (out of 1488) were handled using the Carried Forward (LOCF) method. Since LOCF tends to underestimate changes, it was considered a conservative approach (Lydersen, 2019). To explore whether individual differences in reward and punishment sensitivity influenced outcomes, two repeated measures ANCOVAs were conducted (one for intake and one for liking) with the reward and punishment sensitivity score included as a covariate. Finally, to examine the potential influence of picky eating, two additional repeated measures ANCOVAs were

performed (one for intake and one for liking), including picky eating (measured via the CFRS total score) as a covariate. If the assumption of sphericity was violated, Greenhouse–Geisser corrections were applied. When applicable, pairwise comparisons were conducted with a Bonferroni correction. Results were considered significant at $p < .05$.

RESULTS

Participants' Characteristics

Sixty-two children participated in the study (27 boys, 35 girls; *M_age* = 4.68 years, *SD* = 0.70), with 58 completing both pre- and post-measurements. All participants took part in all experimental conditions as part of the within-subjects design. Demographic variables such as age, gender, and dietary restrictions were collected through a parent questionnaire. Overall, gender did not affect any of the subsequent analyses. Age was positively associated with intake of the control vegetable at the post-measurement ($r = .34$, $p = .009$); therefore, age was included as a control covariate in the intake-related analyses.

Baseline measures

Baseline checks indicated that the vegetables used in the study were rarely or never offered with comparable frequency: 91.9% of parents rarely or never offered purple carrot, 98.4% for blue meat radish, 96.8% for yellow beet, and 77.4% for rutabaga, which was offered slightly more frequently than the others. Children's liking was recoded into a dichotomous measure: 'no' and 'probably no' were grouped together, as were 'yes' and 'probably yes'. Based on this, purple carrot was the most liked vegetable (62.9%), followed by yellow beet (45.2%), rutabaga (43.5%), and blue meat radish (33.9%).

Change in Food Intake from Pre- to Post-Measurement

Descriptive statistics for vegetable intake across the four experimental conditions (positive reinforcement, negative reinforcement, exposure, and control) at both the pre- and post-measurements are presented in Table 1.

The analysis revealed significant main effects of condition, $F(2.45, 139.58) = 13.00$, $p < .001$, and time, $F(1, 57) = 33.10$, $p < .001$. Further, a significant interaction between condition and time was observed, $F(2.69, 153.19) = 18.90$, $p < .001$, indicating that the effect of condition on vegetable intake differed between the pre- and post-measurements (see Figure 2).

Given this significant interaction, separate one-way repeated measures ANOVAs were conducted for the pre- and post-measurements. At the pre-measurement, there were no significant differences between the conditions, $F(3, 183) = 0.06$, $p = .980$, suggesting that baseline intake levels were comparable across all groups. In contrast, the post-measurement showed significant differences between the conditions, $F(3, 171) = 25.96$, $p < .001$.

Pairwise comparisons showed significant differences between all conditions. Vegetable intake was significantly higher in the positive reinforcement condition compared to the negative reinforcement ($t(57) = 3.76$, $p = .002$), exposure ($t(57) = 4.90$, $p < .001$), and control condition ($t(57) = 7.80$, $p < .001$). Intake in the negative reinforcement condition was also significantly higher than in the exposure ($t(57) = 2.60$, $p = .049$) and control conditions ($t(57) = 5.65$, $p < .001$), while the exposure condition yielded significantly higher intake than the control ($t(57) = 2.71$, $p = .042$). So, as hypothesized, the positive reinforcement condition led to the highest vegetable intake at post-measurement, followed by the negative reinforcement, exposure, and control conditions.

Age as a control covariate was not significant, $F(1, 56) = 2.99$, $p = .062$. An additional one-way ANOVA on change scores (post–pre) revealed a significant effect of condition. Follow-up pairwise comparisons on the change scores confirmed the same pattern of results, with the positive reinforcement condition showing the largest improvement, followed by negative reinforcement, exposure, and control (all pairwise p's $< .047$).

Table 1.

Descriptive statistics of intake by condition at pre- and post-measurement

	N	Mean	SD	Minimum	Maximum
Pre PosR	62	2.53	1.42	1.00	5.00
Post PosR	58	4.14	1.19	1.00	5.00
Pre NegR	62	2.56	1.47	1.00	5.00
Post NegR	58	3.76	1.38	1.00	5.00
Pre Exp	62	2.52	1.42	1.00	5.00
Post Exp	58	3.31	1.51	1.00	5.00
Pre Ctrl	62	2.52	1.39	1.00	5.00
Post Ctrl	58	2.74	1.52	1.00	5.00

Notes. PosR = Positive Reinforcement; NegR = Negative Reinforcement; Exp = Exposure; Ctrl = Control; SD = standard deviation.

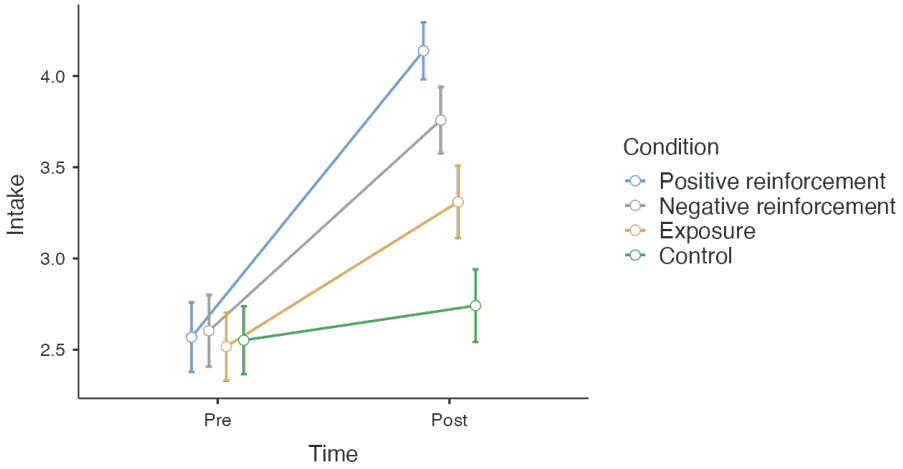


Figure 2. Intake by condition at pre- and post-measurement. The plot shows the estimated marginal means for intake across conditions. Data points at pre-and post-measurement are slightly jittered horizontally to prevent overlap and improve visibility. Error bars represent the standard error of the means.

Change in Food Liking from Pre- to Post-Measurement

Descriptive statistics for liking scores across the four experimental conditions (positive reinforcement, negative reinforcement, exposure, and control) at both the pre- and post-measurements are presented in Table 2.

The analysis revealed significant main effects of condition, $F(2.77, 158.13) = 7.19$, $p < .001$, and time, $F(1, 57) = 25.42$, $p < .001$. Additionally, a significant interaction between condition and time was observed, $F(2.52, 143.37) = 5.55$, $p = .002$, indicating that the effect of condition on liking differed between the pre- and post-measurements (see Figure 3).

Given this significant interaction, separate one-way repeated measures ANOVAs were conducted for the pre- and post-measurements. At the pre-measurement, there were no significant differences between the conditions, $F(3, 183) = 0.49$, $p = .687$, suggesting

that baseline liking scores were comparable across groups. In contrast, the post-measurement showed significant differences between the conditions, $F(3, 171) = 11.70$, $p < .001$.

Pairwise comparisons revealed that liking in the positive reinforcement condition differed significantly from the other conditions. Liking was significantly higher in the positive reinforcement condition compared to the negative reinforcement ($t(57) = 4.15$, $p < .001$), exposure ($t(57) = 4.85$, $p < .001$), and control condition ($t(57) = 5.19$, $p < .001$). The negative reinforcement condition did not differ significantly from liking in the exposure condition ($t(57) = 0.39$, $p > .999$) and control condition ($t(57) = 1.40$, $p > .999$). Lastly, participants in the exposure condition did not report higher liking than those in the control condition ($t(57) = 1.15$, $p > .999$). So, the positive reinforcement condition led to the highest liking at post-measurement, but no differences were present when comparing the negative reinforcement, exposure, and control conditions.

Likewise, a one-way ANOVA on change scores (post–pre) revealed a significant effect of condition. Follow-up pairwise comparisons on the change scores showed that the increase in liking in the positive reinforcement condition was significantly larger than the changes observed in the other conditions (all pairwise *p's* < .021), whereas the remaining conditions did not differ from each other in their change scores (all pairwise *p's* > .198).

Table 2.

Descriptive statistics of liking by condition at pre- and post-measurement

	N	Mean	SD	Minimum	Maximum
Pre PosR	62	2.31	1.18	1.00	4.00
Post PosR	58	3.36	0.91	1.00	4.00
Pre NegR	62	2.23	1.18	1.00	4.00
Post NegR	58	2.69	1.25	1.00	4.00
Pre Exp	62	2.15	1.20	1.00	4.00
Post Exp	58	2.62	1.14	1.00	4.00
Pre Ctrl	62	2.16	1.16	1.00	4.00
Post Ctrl	58	2.45	1.23	1.00	4.00

Notes. PosR = Positive Reinforcement; NegR = Negative Reinforcement; Exp = Exposure; Ctrl = Control; SD = standard deviation.

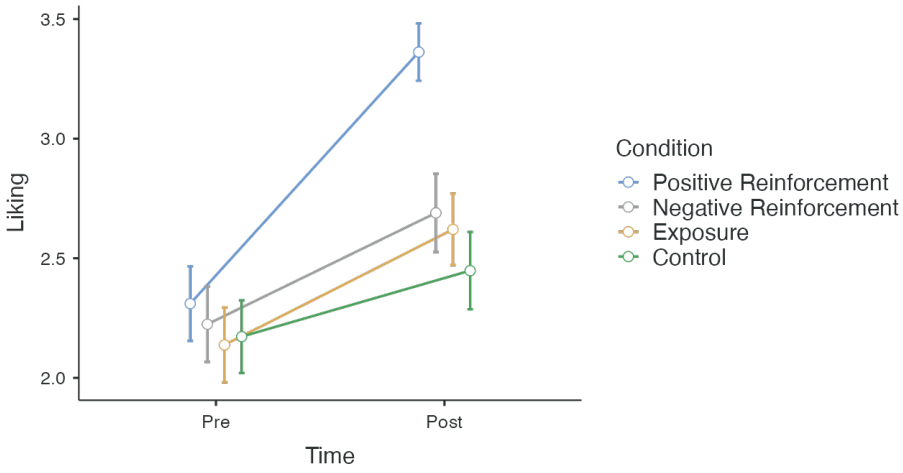


Figure 3. Liking by condition at pre- and post-measurement. The plot shows the estimated marginal means for liking across conditions. Individual data points are slightly jittered horizontally to prevent overlap and improve visibility. Error bars represent the standard error of the means.

Change in Food Intake During the Intervention Sessions

In addition to comparing changes between the pre- and post-measurements, it was also examined how intake evolved across

the 8-day intervention period (i.e., timeline analysis). Specifically, we analyzed intake trajectories over time and across experimental conditions. The control condition was not included in this analysis, as the children were only offered the control vegetable at the pre- and post-assessment, not throughout the intervention period. The dependent variable in this analysis was intake, and liking was not measured during this period. The analysis revealed significant main effects of condition, $F(1.42, 86.71) = 33.09$, $p < .001$, and time, $F(3.35, 204.38) = 14.43$, $p < .001$. No significant interaction between condition and time was found, $F(7.19, 438.56) = 1.18$, $p = .309$. Post hoc comparisons showed significant differences between all conditions. Vegetable intake was significantly higher in the positive reinforcement condition compared to the negative reinforcement condition ($t(61) = 4.44$, $p < .001$) and the exposure condition ($t(61) = 6.52$, $p < .001$). Intake in the negative reinforcement condition was also significantly higher than in the exposure condition ($t(61) = 5.00$, $p < .001$). For the daily intake trajectory, see Figure 4.

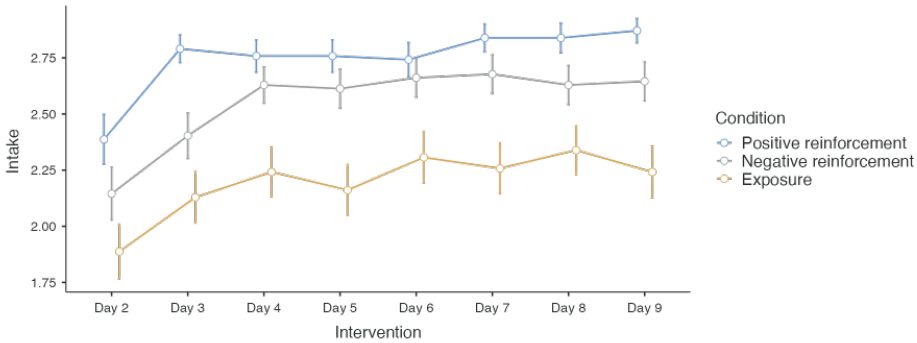


Figure 4. Intake by condition during the 8-day intervention sessions. The plot shows the estimated marginal means for intake across 3 conditions during the intervention phase. Individual data points are slightly jittered horizontally to prevent overlap and improve visibility. Error bars represent the standard error of the means.

Moderating Effect of Reward and Punishment Sensitivity

The mean CGT score was 19.17 (*SD* = 8.15), with scores ranging from 3 to 47. The choice of deck was not significantly correlated with age in months (r(n-2) = -0.20, p = .119). No significant differences between boys (*M* = 17.3, *SD* = 7.90) and girls (*M* = 20.6, *SD* = 8.16) were found using an independent sample t-test , t(58) = -1.56, p = .123.

The CGT score was centered prior to the ANCOVA analysis. No significant effects involving the CGT score were found for either intake or liking (*all F's* < 0.47, *all p's* > .536). These results suggest that individual differences in reward and punishment sensitivity, as measured by the CGT, did not moderate the effects of time or condition on intake or liking, nor did they have a general influence on these outcomes.

Moderating Effect of Picky Eating

The mean CFRS score was 32.2 (*SD* = 7.90), with a range from 15 to 49. Picky eating showed no significant correlation with age in months (r(n-2) = -0.12, p = .363). No significant differences between boys (*M* = 32.0, *SD* = 8.00) and girls (*M* = 32.3, *SD* = 7.93) were found using an independent sample t-test , t(60) = -0.12, p = .914.

The CFRS score was centered prior to the ANCOVA analysis. No significant interaction effects were found between CFRS and the within-subject factors time or condition, on the dependent measure of intake and liking (all *F*'s < 1.32, all *p*'s > .270). However, there was a significant between-subjects effect of CFRS on both outcomes: children with higher levels of picky eating consumed less of the food offered (F(1, 55) = 9.64, p = .003) and liked the food less overall (F(1, 56) = 8.70, p = .005).

DISCUSSION

This study examined the effects of exposure combined with positive and negative reinforcement on children's intake and liking of unfamiliar vegetables, compared to exposure alone and a control condition. Sixty-two children aged 4 to 6 years participated in a 10-day intervention, which included a pre-measurement (day 1), eight intervention sessions (days 2–9), and a post-measurement (day 10). Of these, 58 children completed both the pre- and post-measurements. Four conditions were tested: in the positive reinforcement condition, children earned a cartoon card when they tasted the vegetable; in the negative reinforcement condition, refusal to taste resulted in the loss of a card; the exposure condition involved the opportunity to taste without any rewards or consequences; and the control condition included only the pre- and post-measurements without any exposure in between. Intake and liking of the following unfamiliar vegetables were measured: purple carrot, yellow beetroot, blue meat radish, and rutabaga. The order of the condition and the vegetable assigned to it was balanced. Additionally, the study investigated whether picky eating (measured by the CFRS) and reward and punishment sensitivity (measured by the CGT) moderated the effects of the conditions.

As hypothesized, children in the positive reinforcement condition showed the highest intake and liking of unfamiliar vegetables at the post-measurement. For intake, all conditions differed significantly from each other. For liking, only the positive reinforcement condition showed a significant difference compared to the other conditions. Although the other conditions did not differ significantly from each other, improvements from pre- to post-measurement were evident. These results suggest that positive reinforcement is the most effective strategy for increasing both the intake and liking of unfamiliar vegetables among children. Importantly, the effect was

still present at the post-measurements when no consequences were related to eating the unfamiliar vegetables. The current findings align with previous research demonstrating the beneficial effects of using non-food rewards to encourage children to try vegetables (Cooke et al., 2011; Fildes et al., 2014; Remington et al., 2012; van Belkom et al., 2023). Notably, this is the first study to apply positive reinforcement using only highly unfamiliar vegetables. If future research supports the effectiveness of positive reinforcement combined with repeated exposure in home settings, this approach could be implemented by parents through brief, repeated offering of unfamiliar vegetables paired with simple non-food rewards (e.g., verbal praise or stickers), without pressure to consume. Such strategies could be easily integrated into everyday family routines.

At the end of the 20th century, there was some controversy about the use of rewards to encourage children to eat certain foods, such as promising dessert if they finish their vegetables. According to the Overjustification Theory, proposed by Lepper and Greene (2015), rewarding an action may reduce a child's intrinsic motivation for it. Essentially, if children are given incentives to eat something like peas, they may come to believe they must not genuinely enjoy them. There was some support for this theory, which showed that offering rewards for eating certain foods can actually decrease children's preference for those foods (Rollins et al., 2016). However, later research challenged this view and showed that external rewards seldom reduce intrinsic motivation (Cameron et al., 2001). For instance, using non-food rewards instead of food rewards, smaller rather than larger rewards, and rewards based on how well a behavior is performed, rather than simply that it is performed, appear to be more effective (Eisenberger & Cameron, 1996). This approach was also applied in the current study, and more recent studies mentioned earlier have similarly demonstrated the beneficial effects of using non-food rewards.

Regarding negative reinforcement, it appears to be effective in increasing unfamiliar food intake and may outperform exposure alone in this regard. However, it does not seem to enhance liking as much as positive reinforcement does, possibly due to the inherently aversive or coercive nature of the approach. Interestingly, negative reinforcement did not reduce the children's liking of the vegetables either, indicating that it does not have an adverse effect. The results suggest that strategies using rewards or positive framing to increase desirable behaviors might be more beneficial than those including negative framing. Such an approach aligns with pedagogical recommendations, which generally emphasize the importance of positive reinforcement over punitive measures in fostering healthy behavioral development (Airin & Md Sharif, 2024; Dad et al., 2010; Hardy & McLeod, 2020). Future interventions may therefore benefit from incorporating positive reinforcement techniques to encourage healthy eating behaviors in a more sustainable and psychologically supportive manner.

The reason why exposure did not lead to higher liking compared to the control condition in the current study may be explained by a contrast effect (i.e., a bias where perception is influenced by comparisons to something that came before, making it seem better or worse than it actually is). During the intervention phase, children knew they would receive a cartoon card as a reward for eating one type of unfamiliar vegetable. In contrast, the exposure condition was presented without any reward or consequence, essentially, they were told, "You can eat this, but you won't gain or lose anything from it." This difference in context may have made the exposure condition seem less appealing, reducing the likelihood that children would enjoy it. However, for intake, the results still show that it works for improving intake of unfamiliar vegetables, which is in line with previous research (Caton et al., 2013; de Wild et al., 2015; de Wild et al., 2013; Lakkakula et al., 2010).

An interesting observation from the timeline analysis is that intake differences between intervention conditions emerged rapidly within the first two sessions and remained relatively stable throughout the remaining days. This suggests that the behavioral effects of both positive and negative reinforcement were established after minimal exposure, potentially as early as two instances, and sustained across time during the intervention period. These findings suggest that children's food intake can change quickly when reinforcement is used, which may limit the need for lengthy or repeated interventions. In settings where time or access is limited (e.g., schools or at home), this early responsiveness may enhance feasibility and efficiency. Although the intervention lasted eight days and early effects were robust, the extent to which these effects persist beyond the intervention period remains unknown and needs further investigation.

Contrary to our expectations, there was no effect of reward and punishment sensitivity as assessed by the CGT. This is in contrast with the study by Vandeweghe, Verbeken, et al. (2016), who showed that children high in RS were more likely to taste immediately when rewarded, while children low in RS were more willing to taste when verbally encouraged, but with hesitation. However, a more recent study suggested that individual traits, such as RS, play only a limited and inconsistent role in moderating how effective reward-based interventions are in improving children's acceptance of disliked foods (Vandeweghe et al., 2018). These findings suggest that reward and punishment sensitivity may not significantly impact the effectiveness of strategies like positive reinforcement. Thus, even for children who are not particularly sensitive to rewards, positive reinforcement may still be an effective approach to encouraging the consumption of unfamiliar vegetables.

As expected, picky eating, measured by the parental CFRS questionnaire, had a general effect on both intake and liking of

the unfamiliar vegetables. Children with higher picky eating scores consumed less of the offered food and rated it as less likeable overall. However, despite these lower baseline responses, there was no moderating effect of picky eating. This suggests that even children who are more picky with food can benefit from the interventions, as their response patterns did not differ from those of non-picky eaters. This aligns with previous research showing that repeated exposure interventions can also successfully increase acceptance of vegetables among children with higher levels of food fussiness (Fildes et al., 2014; Wardle et al., 2003).

The present within-subject study offers several notable strengths. It is unique in directly comparing the effects of positive reinforcement, negative reinforcement, exposure, and a control condition. Notably, negative reinforcement has not been previously explored in this context. An additional strength is that, unlike earlier studies that focused primarily on familiar vegetables, this study examined the impact of these interventions on unfamiliar vegetables. The findings demonstrate that positive reinforcement is also effective in encouraging the consumption of unfamiliar vegetables, offering a promising approach to help children overcome food neophobia in a motivating way.

Our study was limited by a narrow age range (4–6 years) and by recruitment that relied on parental consent, which may have introduced self-selection bias. Although this narrow age range reduces the generalizability of our findings to broader developmental periods, it also has the advantage of minimizing age-related confounding, as participants were relatively homogeneous in age. Consequently, future research is needed to examine whether these findings generalize to broader age ranges and to children from diverse demographic or socioeconomic backgrounds. In addition, the study only assessed the immediate effects of the 10-day

intervention, so it remains unclear whether the observed increases in vegetable intake and liking following positive reinforcement are sustained over time. However, previous research by van Belkom (2023) and Horne et al. (2011) found sustained improvements in fruit and vegetable acceptance three and six months after a positive reinforcement intervention conducted in day-care settings with children. Other studies focusing on parent-led interventions have also demonstrated both short- and long-term improvements in children's willingness to eat vegetables and liking when rewards are used (Corsini et al., 2013; Fildes et al., 2014; Remington et al., 2012). Examining the long-term effects of positive reinforcement on the intake and liking of unfamiliar vegetables could be an option for future research. It should also be noted that while the within-subject's design allowed direct comparisons, it is also possible that the conditions influenced each other, leading to contrast effects (as discussed above). Furthermore, the study was conducted in a school setting with a researcher. It would be interesting to explore whether similar effects occur in a home environment. In familiar settings, where children are guided by their parents rather than an unfamiliar adult, different dynamics may come into play, such as established eating routines or the influence of the parent–child relationship. It remains an area for future research whether the use of positive reinforcement is equally effective when implemented by parents, especially considering factors like social desirability or children's responses to familiar versus unfamiliar authority figures. A limitation of the CGT is that the task measures reward and punishment sensitivity on a single continuum, preventing separate assessment of both. Reward and punishment sensitivity do not lie on a continuum but can exist independently of one another (Gray, 1987). Future studies should consider tasks that independently measure high RS and PS for a clearer understanding of their distinct effects.

In conclusion, the present 10-day intervention study demonstrated that positive reinforcement combined with exposure using non-food rewards (i.e., cartoon cards) significantly increased children's intake and liking of unfamiliar vegetables. Among the strategies tested, positive reinforcement proved to be the most effective for improving both outcomes. Additionally, children identified as picky eaters showed lower overall intake and liking. However, picky eating did not moderate the effect of the intervention conditions, meaning that picky eaters responded similarly to each condition. While exposure with positive reinforcement yielded the strongest results, both exposure and exposure plus negative reinforcement also had a positive impact on vegetable intake, though to a lesser extent. These findings suggest that combining positive reinforcement with repeated exposure may be a particularly effective and practical strategy. This approach can be easily implemented by parents and educators to promote healthier eating habits in children, especially when introducing unfamiliar foods.

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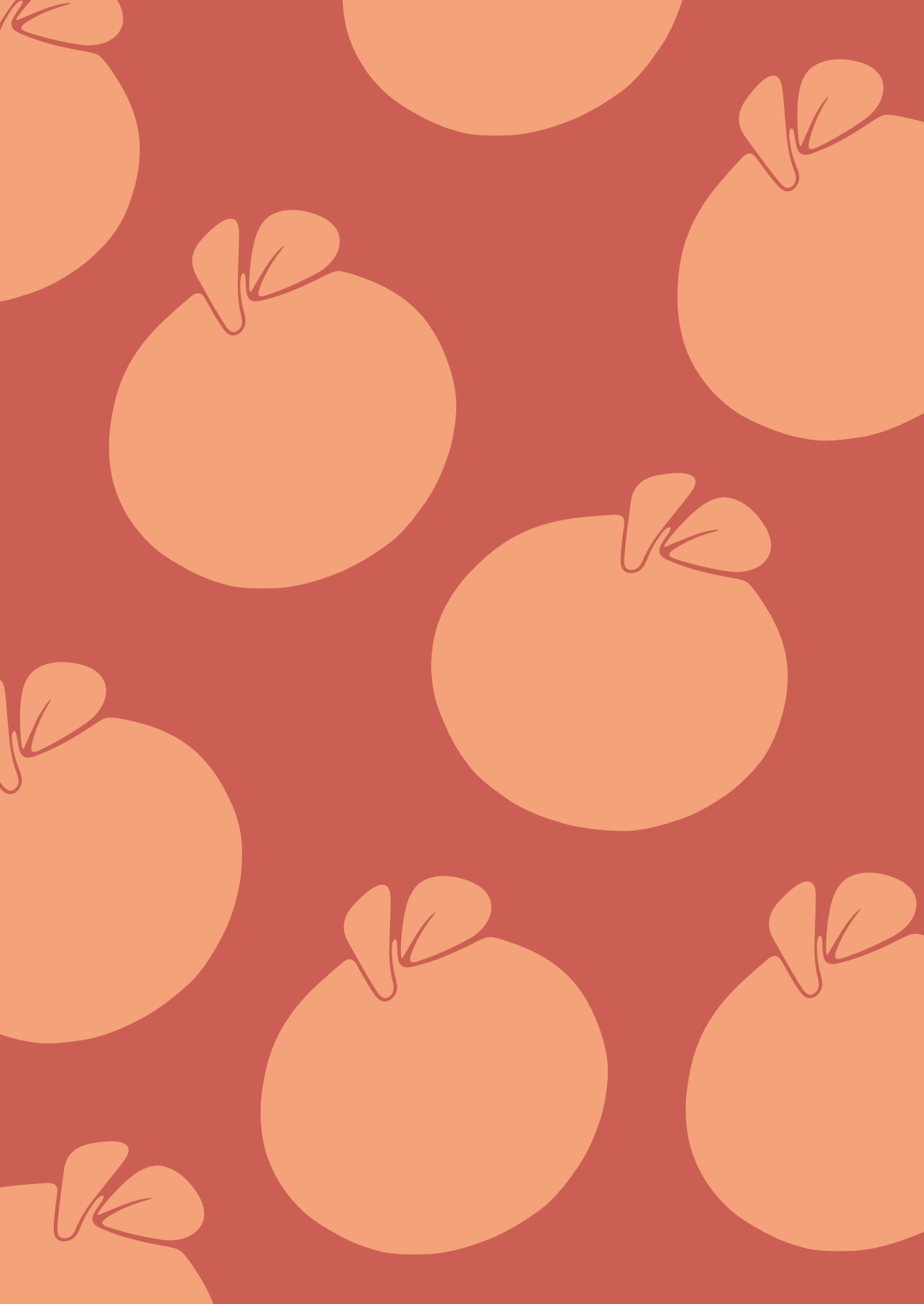
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Chapter 7

General discussion

MAIN FINDINGS

The general aim of this thesis was to examine child-related (cognitive) factors that are related to picky eating, as well as strategies to increase the consumption and liking of fruit and vegetables among children aged 4–6 years. Fruit and vegetable intake among children (and adults) remains well below recommended levels, which is partly due to picky eating (Lynch et al., 2014; van den Brand et al., 2023) Picky eating is a common eating behavior in young children and is associated with negative health consequences in both the short and long term (Chamoun et al., 2018; Nicklaus et al., 2005). In this chapter, the main findings of each study are summarized. This is followed by a discussion of methodological considerations, as well as the theoretical and practical implications of the findings. Finally, directions for future research are outlined.

Child-related (cognitive) factors related to picky eating

Chapter 2 focused on children's inductive reasoning and memory for fruit and vegetables, specifically whether they relied on perceptual food features (color and shape) or on a more abstract but more meaningful feature (food type). To examine this, children completed an induction task in which they generalized properties (based on color, shape or food type) from one fruit or vegetable to another, as well as a memory task assessing what food features they remembered best. Previous research suggests that children higher in picky eating rely more strongly on perceptual features, such as color, which may lead to incorrect generalizations and increased food rejection (for example, assuming that a tomato tastes like a strawberry because both are red) (Rioux et al., 2018a). Children's reasoning about food can also influence what they remember about foods (Vlach, 2016). Therefore, children higher in picky eating may remember perceptual food features better than more abstract features. This study examined the relationship between category-

based induction and memory for fruit and vegetables, and how both relate to picky eating. The results showed no association between inductive reasoning and picky eating, nor between memory and picky eating. However, children's reasoning about food was related to what they remembered: greater use of the abstract feature 'food type' during inductive reasoning was associated with better memory for food type. Overall, children mainly relied on color when making inductive judgments and also showed the strongest memory for the color of fruit and vegetables.

Picky eating is very common in children with autism spectrum disorder (ASD). Based on this fact, **chapter 3** examined whether cognitive traits associated with ASD could also help explain picky eating in typically developing children. The cognitive traits investigated included cognitive flexibility, Theory of Mind (ToM), and global-local processing. In addition, ASD-related traits in the participating children were assessed using a parent-report questionnaire. The results showed no significant relationship between the ASD-related cognitive traits and picky eating. However, a small negative correlation was found between Theory of Mind and the picky eating subscale of the questionnaire, suggesting that lower ToM abilities may be associated with more severe picky eating. Nevertheless, the sample showed low prevalence of ASD-related traits, which might explain the absence of the relation between ASD-related traits and picky eating.

Chapter 4 built on the findings of **chapter 3** and aimed to gain a deeper understanding of the role of social learning in picky eating based on social, emotional, and taste-related cues. Children's eating behavior is partly shaped during mealtimes by observing parents, caregivers, and peers, from which they infer which foods are safe, palatable, and acceptable. In particular, facial expressions serve as important affective cues: positive expressions can enhance food acceptance, whereas negative expressions can reduce willingness

to try foods. However, children may differ in how accurately they interpret these expressions and infer others' taste experiences. These individual differences may influence the extent to which children are affected by food modelling based on social cues and may therefore contribute to variations in picky eating as well as fruit and vegetable intake. To investigate this, children completed tasks assessing facial emotion recognition, basic taste identification (as a control measure), recognition of basic tastes through others' facial cues, and social modelling of a food choice. These measures were examined in relation to picky eating, alongside a proxy measure of fruit and vegetable intake using the Veggie Meter. Overall, no associations were found between facial emotion recognition, recognition of basic tastes through others' facial cues, or social food modelling and either picky eating or Veggie Meter scores. In the social modeling task, children showed a clear preference for a model displaying a subtle smile and were more likely to choose the food that this model had (hypothetically) just tasted. Unexpectedly, worse performance on the control measure of basic taste identification was associated with higher levels of picky eating. In addition, parental picky eating and parental fruit and vegetable intake were positively associated with both child picky eating and child fruit and vegetable intake.

Strategies to increase fruit and vegetable intake and liking

In **chapter 5**, an easy-to-implement strategy to increase fruit intake was examined by inducing mild hunger in children (food-deprived for 3–4 hours) and comparing them with children who were not hungry (food-deprived for less than 30 minutes). The study used a between-subject design, and the hunger effect was tested for both a familiar fruit (apple) and an unfamiliar fruit (lychee). In addition, the moderating role of picky eating was investigated, with the expectation that hunger would have a weaker effect among more picky eating children. Results showed that inducing hunger increased fruit intake, regardless of fruit familiarity. The familiar fruit was consumed in larger

amounts than the unfamiliar fruit. Picky eating did not moderate the relationship between hunger, fruit familiarity, and intake.

In **chapter 6**, a 10-day within-subject school-based intervention was conducted to examine whether combining repeated exposure with positive or negative reinforcement improves unfamiliar vegetable intake and liking compared to exposure alone and a control condition. Non-food rewards (collectible cartoon cards) were used as reinforcement, and intake and liking were assessed for four unfamiliar vegetables (purple carrot, yellow beetroot, blue meat radish, and rutabaga). The study included four conditions: positive reinforcement (tasting resulted in earning a cartoon card), negative reinforcement (tasting prevented loss of a card), exposure (tasting without rewards), and a control condition. The potential moderating roles of reward sensitivity, punishment sensitivity, and picky eating were also examined. Results showed that positive reinforcement led to the highest vegetable intake, followed by negative reinforcement, exposure, and control, with significant differences between all conditions. There was an overall increase in liking across conditions, but the positive reinforcement condition showed a significantly larger increase compared to the other conditions. Reward sensitivity, punishment sensitivity, and picky eating did not moderate the effects, although children with higher levels of picky eating showed lower intake and liking across all conditions.

METHODOLOGICAL CONSIDERATIONS / LIMITATIONS

Before the theoretical and practical implications are discussed, it is important to note that there were also limitations to the studies. The main limitations of this thesis are explained below.

Cross-sectional design and lack of follow-up

First, the studies in this thesis were primarily cross-sectional,

particularly **chapters 2, 3, and 4,** which limits the ability to draw causal conclusions. Although associations between variables were identified, the direction of effects cannot be established. In addition, while **chapter 5** included an experimental manipulation, no follow-up measurements were conducted, which limits insight into whether the observed effects persist over time. **Chapter 6** included a short-term repeated-measures design over a 10-day period. However, no long-term follow-up was included. As a result, it remains unclear whether the observed effects are sustained beyond the immediate intervention period. Future research should therefore make use of longitudinal and longer-term follow-up designs to examine the direction and stability of these effects over time.

Measurement limitations

Furthermore, some of the measures used across the studies were not fully validated. In several cases, shorter or adapted tasks and alternative scoring procedures were used for practical reasons, particularly given the young age of the participants. This was mainly the case for the cognitive tasks in **chapter 3.** While these adaptations improved feasibility in a child sample, they may have affected the reliability and comparability of the findings. In **chapter 4**, two tasks (taste recognition from facial cues and a social modeling of a food choice) were specifically developed for this study. Although these tasks were designed to capture the constructs of interest, their use may limit comparability with existing literature and future replication. At the same time, most of the tasks showed meaningful associations with other measures within the study, providing some support for their convergent validity. The taste recognition from facial cues task was related to the parent-reported picky eating measure (CFRS) and taste identification. The social modeling of a food choice task was related to the facial emotion recognition task. In **chapter 3**, all ASD-trait tasks were related to each other and to the parent-report questionnaire. The exception to this was the global–local task, which

showed no consistent relationships with the other measures. Overall, this pattern suggests that while the measures are not fully validated instruments, they do capture relevant aspects of the constructs under investigation, although with some limitations.

Parent-reported vs. actual behavior

Another limitation of this thesis is the reliance on parental reports of children's eating behavior. In several studies, these reports served as the primary or only measure of eating behavior, particularly in **chapters 2 and 3**, meaning that no direct or objective behavioral measures were included. While parents are often considered appropriate informants given their central role in providing food and observing eating situations, parental reports may not always accurately reflect children's actual behavior. Results from this thesis show that two out of the three studies that included both parental reports and behavioral measures showed an association between parent-reported picky eating and actual behavior. In **chapter 3**, higher CFRS scores were related to lower carrot intake, as well as lower fruit and vegetable intake as measured with the Veggie Meter. Similarly, **chapter 6** showed that higher CFRS scores were associated with lower intake and lower liking of unfamiliar vegetables. In contrast, **chapter 5** did not show a significant association between CFRS scores and fruit intake in the experimental task. These findings are in line with previous literature showing that parent-reported measures are generally associated with children's actual behavior, although these associations tend to be modest, particularly in experimental settings. (Elkins & Zickgraf, 2018; Fernandez et al., 2018; Mourmans et al., 2025; van den Brand et al., 2025). Parents may overestimate or underestimate their child's picky eating due to recall bias, differences in interpretation, or general reporting bias (Alley, 2018; Lee et al., 2022). In addition, parental characteristics may influence reporting. For example, parents' own levels of food neophobia or picky eating may shape how they perceive and evaluate their

child's food preferences and rejection behaviors (Elkins & Zickgraf, 2018). Conversely, relying solely on observed behavior of the child may also provide an incomplete picture, as children's intake can be influenced by contextual factors such as the setting (home versus school), the presence of an experimenter, or the child's comfort level. For instance, children may alter their behavior due to shyness or a desire to please the researcher, which can affect their food intake. Although data in the present thesis were collected in school settings, which are relatively naturalistic, they may still differ from everyday eating environments. Further research in more natural, real-life contexts is therefore needed to enhance ecological validity. Taken together, both parental reports and behavioral measures are subject to different sources of bias, which may contribute to inconsistencies between these assessment methods. This highlights the importance of using multiple methods in future research to obtain a more comprehensive understanding of children's eating behavior.

Sample characteristics and generalizability

The sample across all studies may not be fully representative of the general population. Participation was voluntary and, in most studies, children were recruited through schools, with parental consent required for participation. This recruitment procedure may have led to a self-selection bias, likely attracting parents who are more interested in healthy eating. Although we did include a wide range of picky eating (based on the CFRS), the results may not generalize to all populations. Additionally, the sample in **chapter 4** was recruited through NEMO Science Museum, which may attract families from more privileged backgrounds (due to ticket costs and experience there). This is relevant, as higher socioeconomic status is often associated with healthier eating patterns (Mullie et al., 2010). Future research should specifically target more diverse samples, including individuals from lower socioeconomic backgrounds, who are generally at higher risk for unhealthy eating and have less access to

healthy foods.

THEORETICAL CONSIDERATIONS

The findings of this thesis show that picky eating is present within a typically developing population of children attending regular elementary schools between the ages of 4 and 6 years. Mean scores fall around the midpoint of the CFRS questionnaire range (approximately 30, possible range from 11–55), while also showing substantial variability in all studies. This suggests that picky eating is not an exceptional or pathological phenomenon, but rather a common and continuously distributed behavior in early childhood. This is in line with other picky eating research (Cardona Cano et al., 2015; Nas et al., 2025; Taylor et al., 2015; van den Brand et al., 2023). Conceptualizing picky eating as a spectrum, rather than a categorical construct, therefore appears theoretically more appropriate.

Contrary to previous research (e.g., Foinant et al., 2022; Lafraire et al., 2020; Pickard et al., 2021; Rioux et al., 2016; Zhang et al., 2024; Zohar et al., 2019), the present findings indicate that cognitive factors, such as categorization/inductive reasoning abilities, emotional processing, and autistic traits, do not seem to play a substantial role in explaining picky eating in this age group (4-6 years). The present results challenge existing theoretical assumptions that emphasize cognitive mechanisms as key related mechanisms. However, while the present results do not support robust effects of cognitive factors, they do not fully exclude their involvement, as methodological differences across studies and challenges inherent to research with young children (such as limited attention span, task difficulty, guessing, and parent-report bias) may have attenuated or obscured true associations. Overall, the findings suggest that other factors, such as parental and environmental influences, sensory sensitivity, and exposure, probably play a more prominent role and

should be more centrally integrated into theoretical frameworks of picky eating (Coulthard & Blissett, 2009; Fisher et al., 2002; Podlesak et al., 2017; Rioux et al., 2018b).

With respect to sensory processing, the findings from **chapter 4** on taste identification provide indications that sensory-related mechanisms may be relevant. **Chapter 4** showed that being less able to identify basic tastes (sour, bitter, salty, and sweet) from taste strips was related to higher levels of picky eating. However, given the cross-sectional nature of the data, no conclusions can be drawn about the directionality of this relationship. Children who have more difficulty identifying basic tastes may experience food as more unpredictable or ambiguous, which could make them less willing to try new foods and contribute to picky eating. However, the reverse relationship is also possible: children who are picky eaters and consume a limited variety of foods may have less exposure to different tastes, which in turn may reduce their ability to identify tastes.

Previous research has generally found positive links between sensory factors and picky eating but has primarily focused on sensory sensitivity and taste responsiveness, with less attention given to taste identification abilities. These findings should also be interpreted in the context of a broader body of literature on sensory processing and picky eating. Previous research has often focused on taste sensitivity, particularly sensitivity to bitter tastes (for example, PROP tasters), suggesting that children who are more sensitive to certain tastes may be more likely to exhibit picky eating, possibly due to heightened taste intensity (Cole et al., 2017; Kauer et al., 2015; Keller & Adise, 2016; Rendall et al., 2022). However, findings in this area are mixed, with some studies failing to replicate these associations (Hendriks-Hartensveld et al., 2023; Lumeng et al., 2008). It is interesting to note that the present findings suggest an inverse pattern, with lower taste identification ability associated with higher levels of picky

eating. The present findings thus extend this literature by focusing on taste identification rather than sensitivity, suggesting that not only how strongly tastes are perceived, but also how well they are recognized, may be relevant for understanding picky eating. Overall, this highlights the need for longitudinal and experimental research to clarify causal pathways and to better position different aspects of sensory processing within theoretical models of picky eating (Farrow & Coulthard, 2012; van den Brand et al., 2025; Zickgraf et al., 2022).

The results further demonstrate that social modeling influences children's food choices. Specifically, children showed a clear preference for a model displaying a subtle smile and were more likely to choose foods that this model (hypothetically) had just tasted. This indicates that even minimal positive facial cues are recognized and can guide children's behavior, supporting theoretical accounts of social learning mechanisms in food choice (Barthomeuf et al., 2012; Edwards et al., 2024). However, this modeling effect was not directly related to levels of picky eating. This suggests that while social influences affect immediate food choices, they may not explain stable individual differences in picky eating behavior. Interestingly, a small association between Theory of Mind and the picky eating subscale (**chapter 3**) points to a limited but present role of social-cognitive processing. Together, these findings suggest that social mechanisms mainly influence children's immediate, context-dependent food choices (what a child chooses in a specific moment), rather than contributing strongly to more stable, long-term patterns of picky eating.

Finally, the findings can be interpreted within a broader food environment in which fruit and vegetables typically have a lower hedonic value compared to highly palatable, energy-dense foods (e.g., chocolate, hamburgers, and candy) (Cooke & Wardle, 2005; Drewnowski & Almiron-Roig, 2010). This imbalance highlights a key

theoretical challenge: understanding how children can be motivated to choose and consume less preferred, yet healthier, foods. The present results suggest that motivational mechanisms can play an important role in addressing this challenge. Both intrinsic factors (such as hunger; **chapter 5**) and extrinsic factors (such as positive reinforcement; **chapter 6**) appear to facilitate children's willingness to try and consume both familiar and unfamiliar fruit and vegetables and can even enhance their perceived liking. This indicates that motivational processes should be more explicitly incorporated into theoretical models of picky eating.

PRACTICAL CONSIDERATIONS

The findings of this thesis suggest that relatively simple strategies can be effective in increasing fruit and vegetable intake in young children, including those who are picky eaters, although their overall intake remains lower. In particular, the studies from **chapter 5 and 6** show that both hunger and the combination of repeated exposure with positive reinforcement using non-food rewards can facilitate children's intake and liking of both familiar and unfamiliar fruit and vegetables. The magnitude of these effects is noteworthy: hunger increased intake by approximately 30–100%, while positive reinforcement increased intake by around 60% and liking by approximately 45%. These strategies are relatively easy to implement and can be applied across different contexts, including both school and home settings.

In school settings, this may involve offering fruit and vegetables at moments when children are naturally hungry (e.g., during a mid-morning snack) or presenting them at the start of a meal. Varying the types of fruit and vegetables, rather than repeatedly offering the same items, may further support acceptance (Roe et al., 2013). Positive reinforcement can be applied, for example, by rewarding children

with non-food incentives such as giving a sticker when they try or eat fruit and vegetables. These strategies can also be combined, for instance, by offering fruit and vegetables when children are hungry while simultaneously providing positive reinforcement for trying or consuming them. In addition, peer modeling may support children's willingness to try these foods, as observing classmates eating and enjoying fruit and vegetables can encourage similar behavior (Lowe et al., 2004; Staiano et al., 2016). Schools can be a particularly relevant setting for implementing population-wide approaches to increase fruit and vegetable intake in children (Kovacs et al., 2020; Van Ansem et al., 2013). Structuring regular consumption moments during the school day may promote habitual intake and contribute to the normalization of fruit and vegetable consumption. These behavioral strategies can be further supported by educational components that enhance children's knowledge of healthy eating and the importance of adequate fruit and vegetable intake, thereby addressing both behavioral and knowledge-related aspects of eating (Smith et al., 2020). In addition, school-based approaches may contribute to reducing socioeconomic disparities in access to fruit and vegetables, as not all families have equal resources to provide these foods consistently at home (Chapman et al., 2017; Haynes-Maslow et al., 2013). By offering fruit and vegetables within a structured and familiar school environment, children across different socioeconomic backgrounds may have more equal opportunities for exposure and consumption. Importantly, involving parents in school-based initiatives, for example, through school breakfasts or by encouraging parents to provide healthy foods during school events, may help align strategies across home and school environments, thereby strengthening their overall impact.

At home, parents can apply similar principles by offering fruit and vegetables at strategic moments (e.g., when children are hungry) and by consistently encouraging and positively reinforcing trying

behavior in a non-pressuring way (Holley et al., 2020). Moreover, the observed associations between parental and child fruit and vegetable intake (Veggie Meter) and picky eating suggest that interventions may benefit from a family-based approach, in which not only children but also parents are involved. Although causal directions cannot be determined, these findings suggest that the home environment and parental behaviors may play an important role in shaping children's dietary habits and therefore represent relevant targets for intervention.

At the same time, these strategies need to be considered within a broader obesogenic environment in which children are frequently exposed to highly palatable, energy-dense foods through availability and marketing. This wider context may reduce the effectiveness of the proposed strategies, as children are continuously influenced by competing food cues. Therefore, changes in the wider food environment, such as reducing exposure to marketing of unhealthy foods or implementing clear food policies, may further support healthier choices by decreasing these competing influences (Breda et al., 2020; Sadeghirad et al., 2016; Story et al., 2008).

Taken together, the findings suggest that improving children's eating behavior is unlikely to depend on a single factor. Instead, it appears to involve the interaction between individual, familial, social, and environmental influences. Increasing awareness of effective strategies among parents, teachers, and the environment may support their more consistent use in daily practice. Aligning these strategies across settings, while also addressing the broader food environment, may be key to achieving sustained improvements in children's dietary behavior.

SUGGESTIONS FOR FUTURE RESEARCH

The need for longitudinal evidence

An important direction for future research is the use of longitudinal designs to better understand the directionality of the relationships observed in this thesis. While the present findings provide important insights, the cross-sectional nature of several studies limits conclusions about causality. In particular, longitudinal research is needed to determine whether factors such as Theory of Mind and taste identification influence picky eating, or whether the relationship operates in the opposite direction. Clarifying these pathways may help identify potential targets for future interventions, such as taste education and/or social-cognitive training. In addition, longitudinal designs are needed to examine the long-term effectiveness of the strategies identified in this thesis. Although hunger and positive reinforcement were found to increase fruit and vegetable intake in the short term, it remains unclear whether these effects persist over time. Future studies should therefore include follow-up assessments to determine the durability of these intervention effects.

Exploring the long-term effects of feeding practices

The present findings suggest that certain feeding practices, such as negative reinforcement, may increase intake in the short term but do not appear to improve liking. This raises questions about potential longer-term consequences. Given that such strategies are likely to be commonly used by parents in everyday feeding situations (Grieshaber, 1997; Pelchat & Pliner, 1986), for example, by not allowing children to leave the table before eating their vegetables, it is particularly important to better understand their impact over time. While at the short-term these strategies can be effective (**chapter 6**), future research should examine whether these practices have unintended negative effects, for example, on children's food preferences or eating behavior, or whether their long-term impact is

more neutral than often assumed.

Focusing on specific subgroups

The current thesis only included children attending regular elementary schools, which may limit the generalizability of the findings. Future research should therefore move beyond general population samples and focus more specifically on subgroups of children who may be at greater risk, such as those with higher levels of picky eating or more pronounced autistic traits. Studying these groups may provide more detailed insight into the mechanisms underlying picky eating and help determine whether different processes are at play. In addition, it may be particularly relevant to consider the interaction between child characteristics and family context, such as socioeconomic status. In lower-SES families, limited resources and concerns about food waste may make it more challenging for parents to repeatedly offer rejected foods, potentially reducing opportunities for repeated exposure, which is key for food acceptance (Ghaziani et al., 2022).

Developmental timing: when to intervene

Future research should also further explore at what developmental stage interventions may be most effective. Existing longitudinal evidence suggests that picky eating shows relative stability between the ages of 3 and 5 years (Mascola et al., 2010; Nas et al., 2025), raising the question of whether earlier intervention (before age 3) may be more effective in preventing or reducing picky eating. At the same time, research also indicates that levels of picky eating tend to decrease with age (Cardona Cano et al., 2015), suggesting that picky eating may be more pronounced at younger ages (e.g., around age 3) than later in childhood (e.g., around age 10). This raises an important question not only about when to intervene, but also about which children may require intervention. Rather than assuming that all early picky eating requires immediate intervention, it may be more relevant to distinguish between children for whom picky

eating naturally declines and those for whom it persists over time. Identifying factors that predict this persistence may therefore be more informative for targeting interventions effectively.

At the same time, it may still be valuable to promote general healthy eating habits early in development through low-intensity, preventive approaches, while more targeted interventions could be reserved for children in whom picky eating becomes more persistent or severe. In addition, extending research to older children and adolescents, who often show relatively low fruit and vegetable intake (Moreno et al., 2014), may provide insight into whether similar mechanisms and interventions remain effective across later developmental stages.

CONCLUSION

To address the overall aim of this thesis, this dissertation was divided into two main parts. The first part focused on factors related to picky eating (**chapters 2–4**). The findings from these chapters suggest that picky eating is a common and variable behavior in early childhood (4–6 years), and that cognitive factors such as categorization/inductive reasoning, emotional processing, and autistic traits play no or only a limited role. Instead, the results point towards the potential relevance of other mechanisms, including sensory processing and social-cognitive factors, although the direction of these relationships remains unclear. In particular, associations with basic taste identification and Theory of Mind suggest that both sensory and social-cognitive understanding processes may contribute to variability in picky eating behavior. In addition, associations between parent and child picky eating and vegetable intake were found, suggesting that these behaviors are embedded within the family context, although the extent to which this reflects environmental or genetic influences remains unclear.

The second part of this thesis focused on strategies to increase fruit and vegetable intake (**chapters 5–6**). The findings indicate that relatively simple strategies (leveraging hunger and positive reinforcement using non-food rewards) can facilitate children's willingness to try and consume (unfamiliar) fruit and vegetables, including among picky eaters. These effects were substantial in size, with hunger leading to mean increases in intake ranging roughly from 30% to 100%, and positive reinforcement yielding mean increases of about 60%. Importantly, results further suggested that positive reinforcement can also enhance children's liking of these foods, with mean liking increasing by approximately 45%.

Taken together, this thesis provides new insights into both the underlying mechanisms of picky eating and practical approaches to improve children's dietary behavior, highlighting the importance of considering multiple factors across individual, social, and environmental levels.

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APPENDICES

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SUMMARY

This thesis investigated child-related factors associated with picky eating, as well as strategies to promote fruit and vegetable consumption and liking in children aged 4–6 years. Since fruit and vegetable intake in children remains below recommended levels, understanding factors that contribute to picky eating and the rejection of fruit and vegetables is important for improving dietary habits and supporting long-term health.

The first part of the thesis focused on possible child-related explanations for picky eating. **Chapter 2** examined children's inductive reasoning and memory for fruit and vegetables, focusing on their use of perceptual features (such as color and shape) compared to an abstract but more meaningful feature (food type). Children mainly relied on color when making inductive judgments and also remembered this feature best. This is not always informative as the color of a food does not define the taste (a red tomato does not taste the same as a red strawberry). However, no clear associations were found between picky eating and either inductive reasoning or memory performance. However, children's inductive reasoning was related to what they remembered: greater use of the abstract feature 'food type' during inductive reasoning was associated with better memory for food type.

Chapter 3 explored whether cognitive traits linked to autism spectrum disorder (ASD), including cognitive flexibility, Theory of Mind, and global-local processing, could help explain picky eating in typically developing children. No significant relationships were found between these cognitive traits and picky eating, although a weak negative association suggested that lower Theory of Mind abilities might be related to more picky eating. Overall, ASD-related traits were low in the sample.

Based on these findings, **chapter 4** examined whether factors related to social learning are associated with picky eating, including facial emotion recognition, basic taste identification (as a control measure), recognition of basic tastes via others' facial cues, and social modeling of a food choice. No significant relationships were found between these factors and either picky eating or fruit and vegetable intake, as measured with the Veggie Meter. However, performance on the control task of basic taste identification was unexpectedly associated with picky eating, indicating that lower accuracy in identifying basic tastes is linked to higher levels of picky eating. Furthermore, parental eating behaviors were consistently related to both child picky eating and fruit and vegetable intake, highlighting the potential importance of environmental influences, although shared genetics also explains this relation.

The second part of the thesis examined strategies to increase fruit and vegetable intake. **Chapter 5** investigated whether inducing mild hunger could increase familiar and unfamiliar fruit intake. Results showed that children who were hungry consumed more fruit than non-hungry children, regardless of whether the fruit was familiar or unfamiliar. Picky eating did not influence this effect, so this strategy also seems to work for more picky eating children. So, the simple strategy of giving a child food when it is hungry or at the start of a meal seems useful.

Chapter 6 evaluated a 10-day school-based intervention combining repeated exposure with positive and negative reinforcement and comparing it to exposure alone and a no-intervention control condition. Non-food rewards (collectible cartoon cards) were used as reinforcement and intake and liking were measured using four unfamiliar vegetables in a within-subject design. Positive reinforcement led to the highest increases in intake and liking. Individual differences such as reward sensitivity, punishment

sensitivity, and picky eating did not significantly moderate these effects, although more picky children generally showed lower intake and liking across conditions. Thus, try to increase the intake and liking of (unfamiliar) healthy foods by giving your child a small reward when trying it.

Finally, **chapter 7** summarizes the main results, reflects on methodological considerations, and highlights the implications of the research as well as suggestions for future research. Overall, the findings suggest that cognitive and social factors play a limited role in explaining picky eating, while parental behavior and behavioral strategies such as hunger and positive reinforcement with exposure appear more influential in shaping children's fruit and vegetable consumption. Future research should focus on clarifying the causal and long-term mechanisms underlying picky eating across development, studying vulnerable subgroups, and the durability of the effective interventions.

NEDERLANDSE SAMENVATTING

Deze thesis onderzocht kind-gerelateerde factoren die samenhangen met kieskeurig eetgedrag, evenals strategieën om de consumptie en waardering van groente en fruit te bevorderen bij kinderen van 4–6 jaar. Omdat de inname van groente en fruit bij kinderen nog steeds onder de aanbevolen niveaus ligt, is inzicht in factoren die bijdragen aan kieskeurig eetgedrag belangrijk voor het verbeteren van voedingsgewoonten en het ondersteunen van de gezondheid op de lange termijn.

Het eerste deel van de thesis richtte zich op mogelijke kind-gerelateerde verklaringen voor kieskeurig eetgedrag. **Hoofdstuk 2** onderzocht het inductief redeneren en geheugen van kinderen voor fruit en groente, met aandacht voor het gebruik van perceptuele kenmerken (zoals kleur en vorm) in vergelijking met een abstract maar meer betekenisvol kenmerk (voedseltype).
Kinderen baseerden hun inductief oordelen vooral op kleur en onthielden dit kenmerk ook het best. Dit is echter niet altijd informatief, aangezien de kleur van een voedingsmiddel niet de smaak bepaalt (een rode tomaat smaakt bijvoorbeeld niet hetzelfde als een rode aardbei). Er werden geen significante verbanden gevonden tussen kieskeurig eetgedrag en zowel inductief redeneren als geheugenprestaties. Wel was het inductief redeneren van kinderen gerelateerd aan wat zij onthielden: een sterker gebruik van het abstracte kenmerk 'voedseltype' tijdens inductief redeneren hing samen met een beter geheugen voor voedseltype.

Hoofdstuk 3 onderzocht of cognitieve kenmerken die in verband worden gebracht met autismespectrumstoornis (ASS), namelijk cognitieve flexibiliteit, Theory of Mind en global-local verwerking, kieskeurig eetgedrag bij zich normaal ontwikkelende kinderen konden verklaren. Er werden geen significante verbanden gevonden

tussen deze cognitieve kenmerken en kieskeurig eetgedrag, hoewel een zwakke negatieve associatie suggereerde dat lagere Theory of Mind-vaardigheden samenhangen met meer kieskeurig eetgedrag. Over het algemeen waren ASS-gerelateerde kenmerken laag in de steekproef.

Op basis van deze bevindingen onderzocht **hoofdstuk 4** of factoren gerelateerd aan sociaal leren samenhangen met kieskeurig eetgedrag, waaronder gezichtsherkenning van emoties, identificatie van basale smaken (als controlemethode), herkenning van basissmaken via de gezichtsuitdrukkingen van anderen, en sociale modellering van een voedselkeuze. Er werden geen significante verbanden gevonden tussen deze factoren en kieskeurig eetgedrag of groente- en fruitinname, gemeten met de Veggie Meter. De prestatie op de controletaak voor basale smaakherkenning was echter onverwacht wel geassocieerd met kieskeurig eetgedrag, wat erop wijst dat een lagere nauwkeurigheid in het herkennen van basissmaken samenhangt met meer kieskeurig eetgedrag. Bovendien hingen ouderlijke eetgewoonten consistent samen met zowel kieskeurig eetgedrag van het kind als de inname van fruit en groenten, wat het mogelijke belang van omgevingsinvloeden benadrukt, hoewel gedeelde genetische factoren deze relatie ook kunnen verklaren.

Het tweede deel van de thesis richtte zich op strategieën om de inname van groente en fruit te verhogen. **Hoofdstuk 5** onderzocht of het hebben van lichte honger de consumptie van bekend en onbekend fruit kon verhogen. De resultaten lieten zien dat kinderen die hongerig waren meer fruit consumeerden dan niet-hongerige kinderen, ongeacht of het fruit bekend of onbekend was. Kieskeurig eetgedrag had geen invloed op dit effect, wat suggereert dat deze strategie ook effectief is bij kieskeurigere kinderen. Het simpelweg aanbieden van voedsel wanneer een kind honger heeft of aan het

begin van een maaltijd lijkt dus een bruikbare aanpak.

Hoofdstuk 6 evalueerde een 10-daagse schoolinterventie waarin herhaalde blootstelling werd gecombineerd met positieve en negatieve bekrachtiging en werd vergeleken met alleen blootstelling en een controle conditie zonder interventie. Niet-voedselbeloningen (verzamelbare cartoonkaarten) werden gebruikt als bekrachtiging, en inname en waardering werden gemeten aan de hand van vier onbekende groenten in een binnen-proefpersonen design. Positieve bekrachtiging leidde tot de grootste toename in inname en waardering. Individuele verschillen zoals beloningsgevoeligheid, strafgevoeligheid en kieskeurig eetgedrag hadden geen significante invloed op deze effecten, hoewel meer kieskeurige kinderen over het algemeen lagere inname en waardering vertoonden over alle condities heen. Het geven van een kleine beloning bij het proeven van (onbekend) gezond voedsel kan dus helpen om inname en waardering te verhogen.

Tot slot vat **hoofdstuk 7** de belangrijkste resultaten samen, bespreekt het methodologische overwegingen en belicht het de implicaties van het onderzoek evenals suggesties voor toekomstig onderzoek. Samenvattend, suggereren de bevindingen dat cognitieve en sociale factoren een beperkte rol spelen in het verklaren van kieskeurig eetgedrag, terwijl ouderlijk gedrag en gedragsmatige strategieën zoals honger en positieve bekrachtiging met blootstelling belangrijker lijken in het beïnvloeden van de consumptie van groente en fruit bij kinderen. Toekomstig onderzoek zou zich moeten richten op het verduidelijken van causale en lange-termijnmechanismen van kieskeurig eetgedrag, het bestuderen van kwetsbare subgroepen en de duur van de effectieve interventies over tijd.

IMPACT PARAGRAPH

This thesis focused on understanding why some young children (aged 4–6 years) are selective eaters and examined strategies to improve the intake and liking of fruit and vegetables. This is important because many children do not consume the recommended amounts of fruit and vegetables, even though they are essential for healthy growth, development, and long-term health (Angelino et al., 2019; Boeing et al., 2012; Fulton et al., 2016). A common explanation for low intake in this age group is picky eating, where children are reluctant to try or accept (new) foods, especially fruit and vegetables.

How children's thinking skills relate to picky eating

The studies in **chapters 2, 3, and 4** tested whether differences in child-related factors could help explain why some children are more selective eaters than others. These factors included how children reason about and remember fruit and vegetables, cognitive traits linked to ASD, and how children understand and use emotional and social information. The relation with picky eating was studied for all of these factors. The study in **chapter 4** also assessed sensory abilities, in particular the ability to identify basic tastes, which is relevant for recognizing and responding to taste experiences.

Overall, these child-related factors were not strongly related to picky eating. Children with different levels of these cognitive, emotional, and social abilities did not explain how picky the child was, although a small association was found, indicating that children with lower theory of mind tended to be more picky. In contrast, sensory factors appeared to play a more relevant role: children who had more difficulty identifying basic tastes were more likely to be picky. However, it remains unclear whether this sensory difficulty contributes to picky eating or whether it is a consequence of eating a more limited variety of foods.

Taken together, these findings suggest that picky eating is not mainly explained by how children think or process social information. Instead, environmental and sensory factors seem to be more important. One of these can be the home environment. **Chapter 4** showed that children whose parents also show more selective eating patterns, or who eat fewer fruit and vegetables, are more likely to show similar behaviors. This likely reflects shared eating environments, such as what foods are available at home and how often they are offered, although genetic influences may also play a role.

Also, the findings from the studies suggest that picky eating should not be seen as something that children either have or do not have, but rather as a behavior that varies in degree. The data showed a gradual spread in picky eating, rather than two separate groups. Some children were not picky at all, some were very picky, and many fell somewhere in between. Based on this pattern, it makes more sense to think of picky eating as a continuum rather than dividing children into two groups.

How to increase children's fruit and vegetable intake

Findings from **chapters 5 and 6** show that children's willingness to eat fruit and vegetables is flexible and can be influenced by relatively simple strategies. The first strategy that can be used is hunger: children tended to eat more fruit when they were hungry, which suggests that the timing of meals and snacks can make a difference in the acceptance of healthy and unfamiliar foods. Another effective strategy is adding a positive reward to repeated exposure. Children became more willing to try and increased their liking for unfamiliar vegetables when they were repeatedly offered, using small rewards (collectable cartoon cards) for trying. These effects were also found for children who were initially more selective eaters, showing that change is possible even in children who are more picky eaters. These findings have clear practical implications for everyday life, including

both home and school settings.

At home, parents do not need complex strategies or pressure-based approaches. Instead, simple actions such as offering fruit and vegetables when children are hungry (for example, at the start of a meal) can be effective. Also, regularly offering fruit and vegetables and linking tasting to small positive incentives (for example, praise or a sticker) can help increase children's willingness to try and accept healthy (unfamiliar) foods.

Schools also play an important role because they reach nearly all children and can provide structured, repeated exposure to fruit and vegetables. Offering mandatory fruit and vegetables moments at school when children are hungry, while simultaneously giving the child a reward for trying can make it easier for children to eat fruit and vegetables. Such approaches may also help reduce differences between children from different socioeconomic backgrounds.

At the same time, it is important to recognize that children grow up in a broader food environment where unhealthy foods are widely available and often highly appealing. This makes it more difficult to consistently choose healthier options. Therefore, while individual strategies using timing and positive reinforcement are effective, they are most helpful when supported by a healthier food environment overall.

Overall conclusion

In summary, this research shows that picky eating in young children is not mainly driven by cognitive or social factors, but is instead shaped more by environmental, sensory and motivational influences. Children's eating behavior is flexible and can change depending on the way food is offered. Relatively simple adjustments, such as timing and positive reinforcement together with repeated exposure,

can already lead to meaningful improvements in (unfamiliar) fruit and vegetable intake and liking. These findings shift the focus away from individual cognitive differences and towards the context in which children grow up. They suggest that picky eating is better understood as a behavior influenced by environment and motivation. This provides a practical basis for supporting healthier eating habits in early childhood at home, in schools, and through broader public health approaches.

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CURRICULUM VITAE



Britt Sophie Elisabeth Fleischeuer was born on October 27, 1998, in Sittard, the Netherlands. In 2017, she completed her secondary education (Gymnasium) at Trevianum Scholengroep in Sittard. She subsequently started the Bachelor's programme in Psychology at Maastricht University, which she completed in 2020. During her Bachelor, she developed a strong interest in research, the brain, and behavior. This interest motivated her to pursue the Research Master in Neuropsychology at Maastricht University, from which she graduated in 2022.

During this Research Master, Britt completed both a research internship and a clinical internship, as she was interested in exploring both research and clinical practice. Her clinical internship took place at the Department of Medical Psychology at Zuyderland Medical Center. During her research internship, she contributed to two research projects focusing on (1) the relationship between insomnia and depression in the subacute phase after stroke, and (2) the effectiveness of exposure therapy for persistent post-concussion symptoms.

In 2022, Britt started her PhD project within the Department of Clinical Psychological Science at Maastricht University, under the supervision of Prof. dr. Sjaan Nederkoorn, dr. Pauline Dibbets, and dr. Katrijn Houben. Her PhD research focuses on picky eating in young children, with the aim of improving fruit and vegetable intake.

Alongside her PhD, Britt worked one weekend per month as a pedagogical supervisor for children with behavioral or physical disabilities at N-Joy4Kidz. Since October 2026, she has been working as a psychologist at Youz, a mental health care institution for children and adolescents.

LIST OF PUBLICATIONS

This thesis

Fleischeuer, B., Mourmans, R., Dibbets, P., Houben, K., Hendriks-Hartensveld, A. E., van den Brand, A. J., van Lier, I., & Nederkoorn, C. (2026). I See What You Taste: The Influence of Social Learning on Food Acceptance in Children. *Appetite. Under review.*

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PRESENTATIONS / SCIENTIFIC OUTREACH

2024	Oral Talk	European Association for Behavioral and Cognitive Therapies (EABCT) *Belgrade*
2024	Oral talk	Kinderen Onderzoek Maastricht (KOM) Group *Maastricht*
2024	Organizing committee	Maastricht Child Eating Behaviour Symposium *Maastricht*
2024	Oral talk	Maastricht Child Eating Behaviour Symposium *Maastricht*
2025	Oral talk	Clinical Psychological Science (department) day *Maastricht*
2025	Oral talk	Experimental Health Psychology (EHPS) *Groningen*
2026	Poster presentation	British Feeding and Drinking Group (BFDG) *Wageningen*
2026	Oral talk	Experimental Health Psychology (EHPS) *Paphos, Cyprus*
2026	Organizing committee	Maastricht Child Eating Behaviour Symposium *Maastricht*
2026	Oral talk	Maastricht Child Eating Behaviour Symposium *Maastricht*

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