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

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Abstract

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

associated with the introduction of novel vegetables and furthermore that focusing on conceptual development could be an efficient way to tackle food neophobia and pickiness.

Keywords: children, food neophobia and pickiness, visual exposure, willingness to try vegetables, cognitive performance.

Introduction

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

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

According to the "mere exposure" theory, the exposure to one instance of a given stimulus is sufficient to trigger a more positive attitude toward a subsequent instance of that particular stimulus (Zajonc, 1968). A considerable body of research has therefore investigated whether repeated taste exposure to fruits and vegetables might be employed to enhance children's acceptance and reduce rejections (for a review on food exposure see Cook, 2007; Keller, 2014). There is considerable support for the success of such repeated taste exposure in controlled experimental settings (Birch & Marlin, 1982; Birch, Mcphee, Shoba, Pirok, & Steinberg, 1987) as well as in more ecological settings like home or school environments (Mustonen & Tuorila, 2010; Park & Cho, 2015). However these intervention programs often lead to a significant increase for children's fruit intake, but only minor changes for vegetable intake (Appelton et al., 2016; Evans, Christian, Cleghorn, Greenwood, & Cade, 2012). Additionally these strategies may have limited efficacy in reducing neophobia or pickiness since several studies revealed that 10 to 15 taste exposures to a new food item may be needed for its successful acceptance in preschool-aged children (Birch et al., 1987; Wardle, Carnell, & Cooke, 2005). This is a number greater than most parents are willing or able to provide (Carruth, Ziegler, Gordon, & Barr, 2004).

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

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

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

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

The mechanisms behind mere exposure

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

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

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

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

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

The present study

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

(1) Simple visual exposure to vegetables leads to an increase in the consumption of this food category.

(2) Diverse visual exposure to vegetables (i.e., vegetables varying in color are shown to children) leads to a greater increase in the consumption of this food category than classical exposure paradigms (i.e. the same mode of presentation of a given food across exposure sessions).

(3) Visual exposure to vegetables leads to an increase in the consumption of this food category through a mediating effect of an increase in ease of categorization.

Materials and method

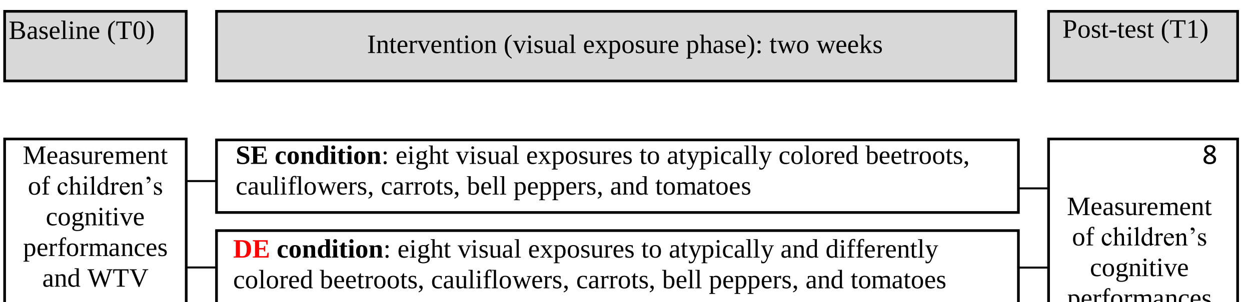
Participants

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

Study design

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

<u>Figure 1: Overview of the experimental design.</u>



Note. SE : simple exposure, CE : diverse exposure, C : control. WTV: Willingness to Try Vegetables.

Visual exposure phase

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

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

(1) *Simple exposure condition (SE)*. In this school, the *same* place mat with five unfamiliar vegetables was presented to children eight times. The main difference between the present study and previous studies of exposure's effect on willingness to try unfamiliar vegetables was the source of unfamiliarity. Indeed in our study, the vegetables themselves

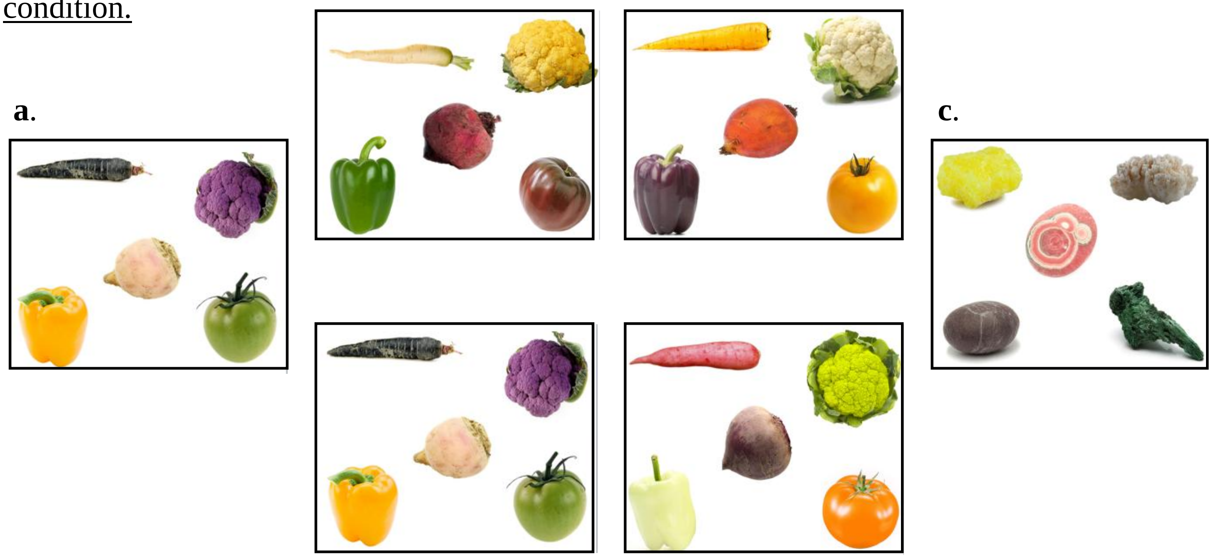
were commonly served in the school canteen but the unfamiliarity came from the atypical color of the vegetables: green tomato, purple cauliflower, white beetroot, yellow bell pepper, and purple carrot (see Figure 1a).

(2) *Diverse exposure condition (DE)*. In this school, place mats presented the same kinds of vegetables as in the previous condition. However, contrary to the *simple exposure* condition where one vegetable was always presented in the same color, in this condition each of the five vegetables was presented in four different atypical and unfamiliar colors (see Figure 1b). Therefore in this condition four different mats were presented to children, for two successive days each.

(3) *Control condition (C)*. In this school, the same place mats with pictures of five stones were presented to children (see Figure 1c). The five stones were selected to match for unfamiliarity and color diversity with the vegetables printed on the mat of the *simple exposure* condition.

<u>Figure 2. Place mats of simple (a) and diverse (b) exposure conditions and control (c) condition.</u>

a. **b**. **c**.



Baseline and post-test

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

Categorization task

This task aimed to assess children's categorization performance. Following the same protocol as in Rioux and colleagues (2016), children were shown successively two blocks of twelve pictures each of fruit and vegetables printed separately on laminated cards measuring 10 x 15 cm. Some vegetables had typical colors (e.g., a purple beetroot), while some had atypical colors (e.g., a yellow beetroot; see Table 2 for the description of the two blocks). For each block, the children were asked to find the vegetable pictures and place them in a box, and then place the other pictures in the other box (the other pictures were the fruit pictures but we did not tell the children they were fruits). The order in which the blocks were provided was counterbalanced across participants. The experimenter then assigned four scores to each participant:

(i) a hit score (i.e. number of cards placed in the vegetable box when the picture was indeed a vegetable).

(ii) A false alarm score (i.e., number of cards placed in the vegetable box when the picture was a fruit).

(iii) A miss score (i.e. number of cards placed in the fruit box when the picture was a vegetable).

(iv) A correct rejection score (i.e. number of cards placed in the fruit box when the picture was indeed a fruit).

Based on these scores we calculated an index of categorization A (ranging from -2.75 to 2.75, with a high score indicating good categorization performance) derived from signal detection theory (Macmillan & Creelman, 2005), but adapted to the needs of experiments with low numbers of stimuli (successfully used in Morin-Audebrand, Mojet, Chabanet, Issanchou, Møller, Köster, & Sulmont-Rossé, 2011).

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

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

Table 2. Description of the two blocks of fruit and vegetable pictures.

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

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

Category-based induction task

This task aimed to assess children's use of taxonomic categories to generalize knowledge. Following the same protocol as in Rioux and collaborators (*under revision*) children were successively shown eight sets of three color pictures: one vegetable target picture and two test pictures (each triad set was printed on a laminated card measuring 21 x 29.7 cm, see Table 3 for a description of the eight sets). For each set, children were told an invented property about the target vegetable picture (such as "contains zuline", to ensure they did not use prior knowledge to draw induction; Fisher, Godwin, Matlen & Unger, 2015). Then they were asked to generalize this property to one of the two test pictures: one fruit similar in color to the target vegetable (*Test picture 1*) or one other vegetable dissimilar in color to the target vegetable (*Test picture 2*)[1]. To heighten the conflict between category membership and color similarity, the labels of the pictures (which can facilitate category recognition) were not provided (the experimenter said “Look at *this*. *It* contains zuline”). The experimenter recorded participants’ responses to the task, assigning a score of 1 to category-consistent responses (i.e., if the participant generalized the property to the other vegetable) and a score of 0 to perceptual-consistent responses (i.e., if the participant generalized the property to the similar-in-color fruit). The scores were then summed across all the sets to obtain the number of category-consistent responses for each participant. This number was divided by the total number of test sets (8) to obtain the child’s category-based induction score (ranging from 0 to 1, with a high score indicating good category-based induction performances).

Table 3. Description of the eight sets of fruit and vegetable pictures.

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

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

Willingness to try vegetables task (WTV)

This task aimed to assess children’s willingness to try unfamiliar vegetables. Following the principle of the seminal food choice task by Pliner and Hobden (1992) eight pieces of vegetables arranged in four pairs were presented to children. Within each pair the

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

same vegetable was presented in two colors: one typical (e.g. orange carrot) and one atypical (e.g. purple carrot). The four pairs of vegetables were as follows: (1) orange and purple carrot, (2) red and green tomato, (3) red and orange bell pepper, and (4) green and yellow zucchini. The typically colored vegetables were *a priori* familiar food items while the atypically colored vegetables were *a priori* unfamiliar vegetables and data collection from the parents supported this assumption: the four atypically colored vegetables were eaten less than once a month on average (all means < 2.3) while the four typically colored vegetables were eaten almost once a week on average (all means > 3). The frequency of consumption of each atypically colored vegetables was significantly lower than its typically colored match (all *ps* > 10^{-7}).

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

(i) Purple carrot and green tomato were present on the place mats in both *exposure* conditions (see Figure 1a and 1b), and are hereinafter referred to as the *color-exposed vegetables*.

(ii) Orange bell pepper was not present on the place mats in the two *exposure* conditions, however pictures of differently colored bell peppers (e.g. yellow bell pepper) were printed on the mats in both *exposure* conditions (see Figure 1a and 1b). Bell pepper is hereinafter referred to as the *kind-exposed vegetable.*

(iii) Yellow zucchinis were not presented on the place mats and neither were differently colored zucchinis (see Figure 1a and 1b). Zucchini is hereinafter referred to as the *non-exposed vegetable.*

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

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

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

Statistical analysis

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

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

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

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

Results

Evaluation at baseline

The characteristics at baseline (T0) of the children who fully completed the study are presented in Table 4. Children in the *control* condition were significantly younger than those in the other two conditions. Additionally, children in the *diverse exposure* condition ate atypically colored vegetables significantly less often at home, compared to the two other conditions.

Table 4. Characteristics of the study population at baseline.

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

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

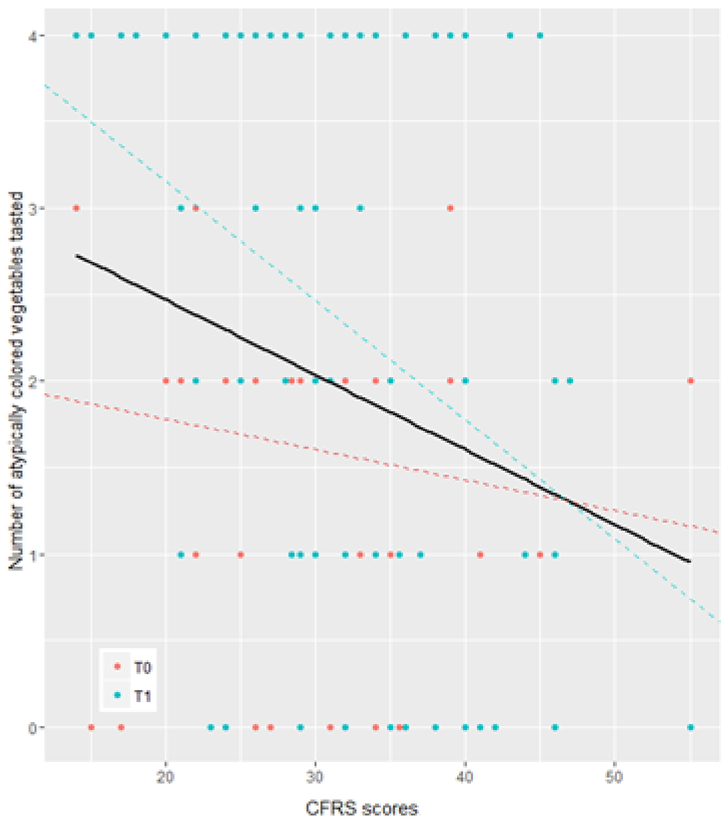
Does simple and diverse visual exposure to vegetables lead to an increase in the consumption of this food category (H1 and H2)?

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

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

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

Figure 3. Children's willingness to taste atypically colored vegetables as a function of their food neophobia and pickiness scores (CFRS scores).



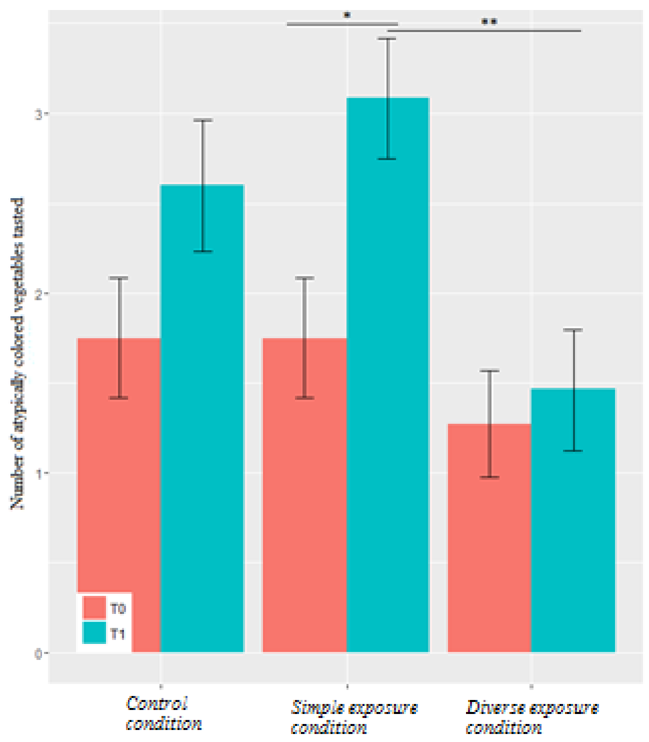
Note. The Spearman coefficient correlation indicated a significant and negative correlation between children's eating patterns and their food neophobia and pickiness levels (r = -0.22, p = 0.0067) across time (black line). The correlation was not significant atT0 (r = -0.11, *ns,* red dashed line) and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

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

However, contrary to the second hypothesis (H2), this post hoc analysis revealed that post-test (T1), the children in the *simple exposure condition* ate significantly more atypical vegetables (M = 3.09, SD = 1.44) than children did in the *diverse exposure condition* (M =

1.46, $SD = 1.53$, $p = 0.0014$). Children in the *diverse exposure condition* did not significantly increase their consumption at T1 from T0.

<u>*Figure 4.* Children's willingness to taste atypically colored vegetables as a function of experimental condition and time.</u>



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

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

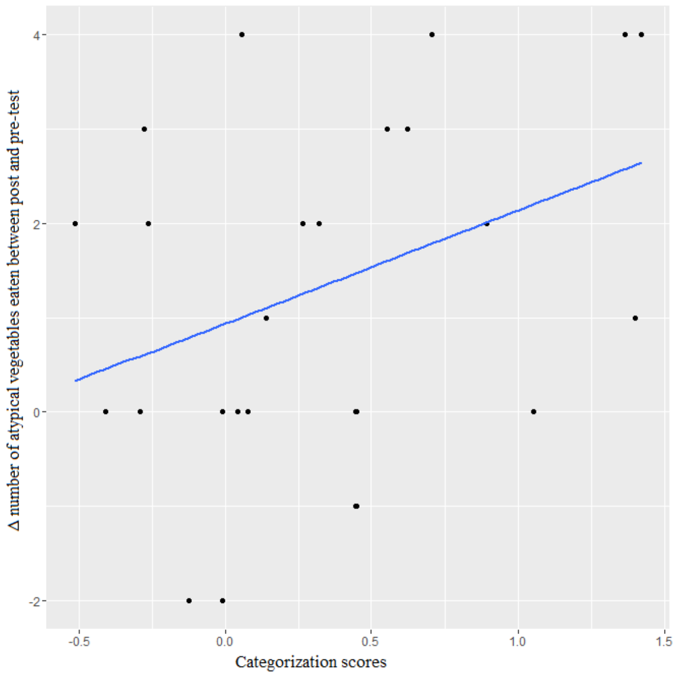
Does visual exposure to vegetables lead to an increase in the consumption of this food category through a mediating effect of the increase in ease of categorization (H3)?

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

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

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

Figure 5. Children's change in willingness to taste atypically colored vegetables between T1 and T0 as a function of categorization score.



Note. The Spearman coefficient correlation indicated a nearly significant and positive correlation between categorization performance and the difference in number of atypically colored vegetables eaten, between T1 and T0 ($r = 0.42$, $p = 0.032$.

Discussion

The goal of the present study was to explore further the potential for visual exposure and to investigate the mechanisms responsible for its impact. We tested the effectiveness of an intervention among children, who were exposed to different pictures of vegetables, compared with a control group of children, who were not exposed these pictures.

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

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

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

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

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

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

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

Another plausible explanation is that, by revealing to children that vegetables can have different colors, we did succeed in lowering the predictive value of color for inductive reasoning in the food domain. However, as vegetables were not labeled during the intervention phase, we failed to provide alternative reliable cues, such as labels, to support categorization and category-based induction. Indeed, during the 2-week exposure intervention, the place mats were simply set on the table in the cafeteria. An experimenter was present to ascertain whether children paid attention to the mats by telling them “Look at the different vegetables you have on the mats! Look they have different colors!”, but did not name the five vegetables depicted on the mats. Even if we named the vegetables during the individual WTV task, it is possible that by lowering the predictive power of color during the intervention, we unwittingly increased the children’s state of uncertainty about the atypically colored vegetables. As a possible consequence children picked the vegetables that were familiar to them at post-test, namely the typically colored ones, to be sure of the consequences of ingestion. Tuorila and colleagues (1994) accordingly found that label information reduces uncertainty about the identity of a novel food and initially reduced negative responses to this food. Similarly Morizet, Depezay, Combris, Picard, & Giboreau (2014) found that 8- to 11-year-old children more often chose the familiar presentation of a familiar vegetable when no label information was given. Conversely, the availability of a label led to an increase in consumption of the new presentation of a familiar vegetable (Morizet et al., 2014). The greater correlation between CFRS scores and the number of atypically colored vegetables eaten at *post-test, compared to baseline* (see Fig.3, red dashed line) may support this hypothesis. Neophobic and picky children, who supposedly reject a particular food item because there is not an acceptable similarity between the item and its representation in their mind (Brown, 2010; Dovey et al., 2008; Lafraire et al., 2016; Rioux et al., 2016), were therefore negatively impacted by this increased uncertainty about the predictive power of color. Whether this type of diverse exposure intervention would be effective if the labels were provided during the exposure manipulation remains to be seen.

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

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

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

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

Limits and perspectives

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

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

Conclusion

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

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