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The effect of nutritional labels on the facilitation of food image detection

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ABSTRACT

The abundance of reduced-energy food products in modern society means consumers are frequently exposed to foods with similar sensory characteristics but differing nutritional values (e.g., sugar or sugar-free beverages). This inconsistency between sensory cues and nutritional content has been suggested to impair eating regulatory mechanisms such as flavor-nutrient learning and conditioned satiety. This research aimed to examine whether nutritional labels can serve as a tool to counteract this presumed impairment. Specifically, we investigated whether nutritional labels could modulate the previously observed attentional bias toward food stimuli. Across two experiments, we explored (1) whether attentional bias is influenced by the nutritional value of the food (Experiment 1) and (2) whether this bias can be modulated by a pre-feeding phase in which participants consumed a food item presented either with or without a nutritional label that signaled high or low caloric content (Experiment 2). Our results replicate the finding that attentional biases toward foods are modulated by their nutritional value. However, the effect of nutrition labels remains inconclusive. Future research should explore whether using this methodology with alternative nutritional label formats would be more effective.

1. Introduction

The prevalence of obesity has increased dramatically in recent decades, reaching pandemic proportions and posing a significant public health concern (World Health Organization [WHO], 2024; Blüher et al., 2023). According to the WHO (2024), global adult obesity has more than doubled since 1990, while adolescent obesity has quadrupled. Overweight and obesity result from a long-term positive imbalance between calorie intake and energy expenditure (Blüher, 2019). The causes of this imbalance are multifactorial, involving environmental, psychological, and biological factors (e.g., Blüher, 2019; WHO, 2024). Among the environmental contributors is overexposure to so-called obesogenic environments (Berthoud, 2012; Swinburn et al., 1999). These environments are characterized by the widespread availability of highly caloric and palatable foods; the presence of appetitive cues—such as food advertisements, smells, and images—that can trigger eating even in the absence of hunger; and the promotion of sedentary lifestyles (Berthoud, 2012; Martin, 2016; van den Akker et al., 2018). Collectively, these factors promote an energy imbalance between calories consumed and expended, helping to explain the rising rates of obesity and overweight in recent decades.

In this context, humans would be expected to rely on basic intake regulatory mechanisms that help prevent overeating by adjusting intake according to calories consumed and expended, thereby maintaining energy homeostasis. In non-human animal species, a well-documented phenomenon known as *flavor-nutrient learning* has been observed (e.g., Capaldi et al., 1994; Gil et al., 2014; Myers, 2018). This refers to the ability to learn associations between sensory cues and their nutritional consequences—for example, learning that a sweet taste is typically followed by a substantial caloric reward. Through this learning process, food preferences are also shaped: when a new flavor becomes associated with an energy boost, liking for that flavor increases (e.g., Palframan & Myers, 2016). This type of learning also gives rise to *conditioned satiety* (Booth, 1972; Martin, 2016; Yeomans, 2012), defined as the ability to stop eating based on prior associations between a food and its post-ingestive effects. This mechanism helps determine appropriate portion sizes and can prevent overeating, particularly with energy-dense foods. Both flavor-nutrient learning and conditioned satiety are considered adaptive mechanisms for survival in natural environments where food is scarce. Flavor-nutrient learning promotes the detection and preference

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for high-calorie foods, while conditioned satiety helps avoid the discomfort or harm associated with overeating (Yeomans, 2012).

Given the wide variety of high-calorie products present in obesogenic environments, these two learning mechanisms — flavor-nutrient learning and conditioned satiety — should be particularly valuable in helping to prevent excessive food consumption and, ultimately, obesity. However, while evidence for flavor-nutrient Learning in animal models is robust and well-documented (e.g., Azzara & Sclafani, 1998; Harris et al., 2000; Myers, 2007; Palframan & Myers, 2016; Sclafani & Glendinning, 2005; Wald & Myers, 2015), its replication in human models has yielded inconsistent results (e.g., Attuquayefio et al., 2020; Brunstrom & Mitchell, 2007; Gould et al., 2018; Zandstra et al., 2002). This inconsistency has led to the phenomenon being described as "elusive," with some studies reporting positive findings and others reporting null results (for reviews, see Yeomans, 2012; Martin, 2016). One proposed explanation for the lack of consistent evidence in humans is the obesogenic nature of the environments in which we live (Martin, 2016). As previously discussed, a key feature of these environments is the high variability of food products. This variability may occur at the sensory level—where many similar products differ subtly in sensory attributes (e.g., different types of crisps; González et al., 2018)—or at the nutritional level—where products of the same type vary significantly in their caloric content (e.g., Hardman et al., 2015). Regarding the latter, it has been hypothesized that the presence of many similar food items with widely varying caloric values disrupts the proper formation of flavor-nutrient associations. A clear example is the widespread availability of "light" or "zero" products, such as sugar-free beverages. Inconsistent exposure to these products may weaken the association between sweet taste and caloric intake. Supporting this idea, some animal studies that simulate such dietary variability by exposing rats to non-caloric sweeteners (e.g., saccharin) have shown that these animals tend to overconsume sweet foods and gain more weight than controls (e.g., Davidson et al., 2011; Swithers, 2013; Swithers et al., 2009). However, it is worth noting that other studies have reported the opposite pattern of results (e.g., Boakes et al., 2016; González et al., 2023; Tey et al., 2017).

Nevertheless, the difficulty in demonstrating flavor-nutrient learning through direct food experiences does not rule out the possibility that food-calorie associations can be acquired through mechanisms other than flavor-nutrient learning or conditioned satiety. One such alternative is the acquisition of knowledge or preferences based on explicit information. In this vein, Gould et al. (2018) were the first to examine how learning explicit food-calorie information through nutritional labels interacts with flavor-nutrient learning. Interestingly, the authors found that after several days of consuming nutrition-labeled foods, the presence of these labels prevented flavor-nutrient learning, as measured by liking and total intake. In contrast, participants in the unlabeled condition showed increased liking and intake of high-calorie foods compared to low-calorie ones, consistent with predictions from flavor-nutrient learning. Given the potential challenges in acquiring flavor-nutrient learning in today's complex food environments, studies like that of Gould et al. (2018) are particularly valuable. They suggest the potential utility of external tools, such as nutritional labels, in supporting intake regulation and preventing overeating. While the underlying learning processes—implicit (flavor-nutrient learning) versus explicit (label-based learning)—may differ, the content of what is learned in both cases (i.e., food-calorie associations) appears to be similar.

Studies on attentional biases further suggest that humans are capable of visually distinguishing between the caloric values of different foods. In visual search tasks, people tend to detect food-related stimuli faster than neutral stimuli (e.g., de Oca & Black, 2013; Nummenmaa et al., 2011; Pimpini et al., 2022; Sato et al., 2020; Sawada et al., 2017, 2019). Food has both hedonic and motivational properties, making it a rewarding stimulus that captures attention more effectively than non-rewarding stimuli. Importantly, prior experiences—whether positive or negative—with specific foods also influence their perceived value, salience, and attentional capture (Yeomans et al., 2021). Among the factors modulating this effect is the expected nutritional value of the food: high-calorie foods are detected more quickly than low-calorie ones, suggesting a capacity for visual discrimination based on caloric content (Sawada et al., 2017). This implies that humans possess some degree of food calorie knowledge, though the source of this knowledge remains unclear. Such attentional biases have been interpreted as adaptive, supporting the rapid detection of valuable food items in environments where there is a risk of undernutrition. Moreover, this attentional bias may play a dual role—facilitating food detection and supporting intake regulation: evidence shows that attentional capture by food stimuli is reduced when individuals are sated compared to when they are hungry (Piech et al., 2010; Sawada et al., 2019). This modulation by hunger state reflects *aliesthesia*—the phenomenon whereby the perceived value of a stimulus changes according to physiological needs (Cabanac, 1971). It is important to note that some authors have noted inconsistencies in the basic effect and its modulations (Sawada et al., 2017), as results appear to be sensitive to variations in the visual characteristics of the stimuli and the specific attentional tasks used (e.g., de Oca & Black, 2013; Neal et al., 2023; Nijs & Franken, 2012; Nummenmaa et al., 2011; Sato, 2021). Therefore, further research is needed to resolve these inconsistencies and ensure the robustness and validity of attentional bias effects in this domain.

This research aimed to investigate nutritional labels as potential predictors of the nutritional properties of foods, as well as regulators of preferences and intake. In the first study, we attempted to replicate the effect of attentional bias toward food and its modulation by nutritional value using a visual search task (de Oca & Black, 2013; Nummenmaa et al., 2011; Sato et al., 2020; Sawada et al., 2017, 2019). In the second study, we examined whether nutritional value, as conveyed by labels, could modulate participants' motivational states using both implicit (attentional bias) and explicit (subjective ratings) measures. All participants consumed the same type of crisps, which were assigned one of three labels: High Calorie, Low Calorie, or an unlabeled control. We hypothesized that participants who consumed crisps labeled as high in calories would experience a greater state of satiety following prefeeding. This heightened satiety would reduce attentional bias for food in the visual search task and would be reflected in higher subjective satiety ratings. Furthermore, in line with mechanisms similar to flavor-nutrient learning, we expected that participants exposed to the high-calorie label would perceive the crisps as more appetizing (Wanting), pleasurable (Liking), and satiating (Expected Satiation). A final food consumption test was conducted at the end of the experiment to assess whether nutritional labels influenced total crisp intake. We predicted that participants in the high-calorie label condition would consume fewer crisps, consistent with a process analogous to conditioned satiety.

1.1. Experiment 1

The main objective of this experiment was to replicate the attentional capture effect of food images compared to neutral images, as reported by Sawada et al. (2017) while adapting the procedure to a different target population. In their study, Sawada et al. (2017) employed two categories of food stimuli — Fast Food (FF) and Traditional Japanese Food (TF) — and kitchen utensils as neutral stimuli (NE). For our adaptation, we replaced the TF category with foods typical of the Mediterranean diet to better suit the Spanish population. Additionally, we substituted kitchen utensils with images unrelated to eating behavior to serve as neutral stimuli. We expected the following pattern in reaction times: FF < TF < NE. Note that this pattern was hypothesized for participants experiencing mild hunger.

2. Method

2.1. Participants

Sample size was calculated using G*Power software (Faul et al., 2007) for a repeated measures analysis of variance (ANOVA) with a within-subjects factor (three levels), an $\alpha = 0.05$, power ($1 - \beta$) of 0.95, and ε of 0.5. For a medium effect size ($f = 0.25$), the analysis indicated a minimum sample size of 43 participants. Since this experiment was focused on intake and included stricter inclusion criteria, we initially recruited more participants to account for later exclusions. Sixty-seven participants (54 female, 10 male, and 3 identifying as other) from the University of Granada took part in the experiment. The mean age was 22.2 years (range: 18–48; $SD = 6.1$). Exclusion criteria were: 1) having eaten within two hours prior to the experiment, 2) having a current or past diagnosis of an eating disorder (e.g., anorexia, bulimia), and 3) following a vegan or vegetarian diet (as the target images contained meat-based foods). Following recruitment, 13 participants were excluded due to either a reported history of eating disorders ($n = 6$) or adherence to vegetarian or vegan diets ($n = 8$). The final sample comprised 54 participants, whose data were included in the analysis.

The present study was conducted in accordance with the 1964 Declaration of Helsinki. The experimental procedures were approved by the Ethics Committee at the University of Granada (Number issued by the Ethical Committee: 2246/CEIH/2021). All participants provided written informed consent before beginning the experiment and received academic credits as compensation.

2.2. Apparatus and stimuli

The main stimuli consisted of 20 images divided into four categories: Fast Food (FF), Traditional Food (TF), Neutral (NE), and Fillers (Cars), with five images per category. FF stimuli included a hamburger, a slice of pizza, a hot dog, a donut, and French fries. TF stimuli (adapted to the Mediterranean diet) included a meat steak, a green salad, a fish, a lasagna, and a fruit cocktail. NE stimuli were images unrelated to food, including a watering can, a hammer, a paintbrush, pliers, and a broad brush. Filler stimuli consisted of five cars, varying in color and shape.

All experimental images were obtained from the *food. Pics* database (see Blechert et al., 2019), except for the car images, which were sourced from the internet. This database includes detailed information about the physical properties of each image, allowing for the analysis of perceptual features to ensure appropriate image selection. This process helped minimize potential confounding variables—such as saliency-driven "pop-out" effects—that could influence attention in the visual search task. The corresponding perceptual values (including RGB color channels, intensity, contrast, complexity, and spatial frequencies) of the target images were analyzed using a one-way ANOVA with image type (FF, TF, NE) as the main factor. This analysis revealed no significant differences across image types, Greens; $F(2,12) = 3.27$; $p > 0.05$, Spatial Frequency $F(2,12) = 1.75$; $p > 0.05$, Reds, Blues, intensity, contrast, complexity $Fs < 1$. Full details of the image analyses and datasets are available at the following Open Science Framework repository:https://osf.io/gucx4/?view_only=de50a87ae03c45a18446516937701bbf

All stimuli were presented in a 2 × 2 array against a white background. Participants completed the tasks on a Full HD screen (1920 × 1080 resolution, 60 Hz, 21.5″ display). The task was programmed and administered using Labvanced experimental software (Finger et al., 2017). Responses were recorded using a standard Spanish QWERTY keyboard and a computer mouse.

2.3. Procedure

Participants were instructed not to eat for at least two hours prior to the experiment. Experimental sessions were conducted individually in a controlled cabin between 10:00 a.m. and 8:00 p.m. Each participant was seated approximately 60 cm from the monitor.

Upon arrival and signing the informed consent form, participants completed a brief questionnaire assessing demographic information (gender and age) and feeding-related variables. This included: (1) confirmation of adherence to the 2-h food deprivation requirement, (2) the elapsed time since their last meal, and (3) a self-reported hunger rating using a 5-point Likert scale (1 = very hungry, 5 = very full).

Following the questionnaire, participants completed the visual search task. The procedure was adapted from Sawada et al. (2017). Participants were instructed to maintain their gaze at the center of the screen throughout the task. Each trial began with a fixation cross (500–800 ms), followed by the presentation of four images in a 2 × 2 array, which remained on the screen until a response was made. Trials were divided into two types: SAME trials, where all four images were identical filler stimuli (cars), and DIF trials, where one of the four images was a target (FF, TF, or NE) among three identical cars. Trial type, target image, and target position were randomized across trials, ensuring that each image and each position appeared equally across the experiment. For each target category (FF, TF, NE), 40 trials were presented (8 repetitions per image) for a total of 120 DIF trials. Participants were instructed to respond as quickly and accurately as possible by pressing the D or J key to indicate whether all images were the same (SAME) or one image was different (DIF). The key-response mapping (D vs. J) was counterbalanced across participants. Prior to the main task, participants completed 25 practice trials, consisting of 5 SAME trials per condition plus 10 DIF per trials (see Fig. 1).

At the end of the experimental task, participants completed a series of 7-point Likert scales to evaluate the target stimuli. For the food-related images (TF and FF), participants responded to the following questions: "How much do you like this food?" (Liking); "How much do you want to eat this food?" (Wanting); "How much do you think a portion of this food would satiate you?" (Expected satiety); "How often do you eat it?" (Frequency); "How healthy do you consider it to be?" (Healthiness) and "How familiar is this picture?" (Familiarity). For the neutral stimuli (NE), participants rated: "How much do you like this object?" and "How familiar is this picture?". These evaluations were included as supplementary material, as they were not the primary focus of the study. Finally, participants completed a brief questionnaire assessing dietary background, including history of eating disorders and current dietary habits.

2.4. Open access

All data, stimuli, and analyses from the present study are fully and freely available at the following link: https://osf.io/gucx4/?view_only=de50a87ae03c45a18446516937701bbf.

2.5. Data analysis

All analyses were conducted using JASP team (2024). General linear model null hypothesis testing was applied, with a significance threshold of $p < 0.05$. When appropriate, Greenhouse–Geisser corrections were used for mixed factorial ANOVAs to account for violations of sphericity (Greenhouse & Geisser, 1959). Effect sizes were reported using partial eta squared (η^2_p).

Reaction times (RTs) from correct responses were processed following the outlier removal procedure described by Tabachnick and Fidell (2001). Raw RTs were first converted into standardized *z*-scores, and data points exceeding ±3 standard deviations were identified as outliers. Outliers were removed recursively, recalculating *z*-scores after each cycle until no data points exceeded the ±3 SD threshold. This process resulted in the exclusion of 7.17 % of the data.

For each participant, mean RTs were calculated across the three experimental conditions (Fast Food [FF], Traditional Food [TF], and Neutral Stimuli [NE]). These scores were submitted to a repeated-measures ANOVA (RM-ANOVA) with Condition as a within-subject

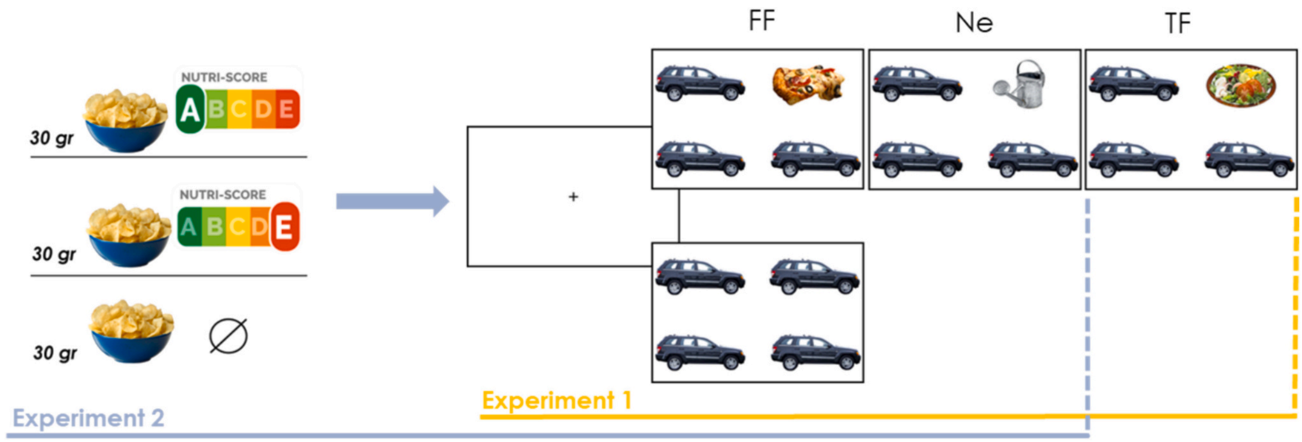

Fig. 1. Procedure of Experiments 1 and 2.

factor. Post hoc comparisons were conducted using Holm's correction to adjust for multiple comparisons. The analysis was guided by the hypothesis that attentional capture would follow the pattern: FF < TF < NE.

3. Results

Participants initially reported a mean hunger score of 2.5 and had not eaten for an average of 6.7 h before the experiment.

Analysis of the visual search task revealed a significant main effect of Condition in the RTs analysis, $F(1.94, 102.66) = 13.17$, $p < 0.001$, $\varepsilon = 0.97$, $\eta_p^2 = 0.20$. However, no significant effect was found for error rates, $F(1.88, 99.87) = 1.38$, $p = 0.255$, $\varepsilon = 0.94$, $\eta_p^2 = 0.02$. Planned pairwise comparisons using *t*-tests showed that participants responded significantly faster to Fast Food (FF; $M = 513$ ms, $SE = 6.8$) than to Traditional Food (TF; $M = 519$ ms, $SE = 7.5$), $t(53) = -2.45$, $p = 0.048$, and significantly faster to FF than to Neutral stimuli (NE; $M = 526$ ms, $SE = 7.1$), $t(53) = -5.13$, $p < 0.001$. Reaction times were also significantly faster for TF compared to NE, $t(53) = -2.68$, $p = 0.025$ (see Fig. 2). These results indicate that food-related stimuli are detected more rapidly than neutral stimuli, with FF images capturing attention more effectively than TF.

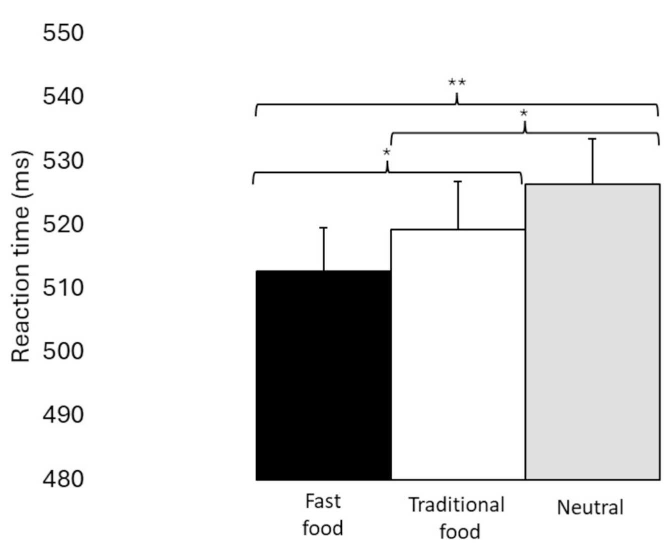

Fig. 2. Reaction times in the three conditions of the visual search task.

3.1. Experiment 2

Having demonstrated the basic effect of attentional bias toward food stimuli with this task, the aim of Experiment 2 was to examine whether perceived satiety—and thus attentional capture—could be modulated by nutritional labeling. Participants were randomly assigned to one of three groups based on the nutritional information presented with the food: Nutri A (Low-calorie label), Nutri E (High-calorie label), or an unlabeled Control group. We hypothesized that participants who consumed food with the Nutri E label would experience higher levels of satiety than those in the Nutri A and Control conditions. This label-induced modulation of physiological state was expected to influence both explicit measures (self-reported hunger) and implicit measures (attentional bias in the visual search task). Specifically, we predicted that participants in the Nutri E group would exhibit a reduced or absent attentional bias to food stimuli compared to the other groups. A secondary aim was to explore how nutritional labels affect the hedonic, motivational, and satiating evaluations of crisps (expected satiation), following a mechanism similar to flavor-nutrient learning. We expected that participants exposed to the Nutri E label would rate the crisps as more hedonic, more desirable, and more satiating than those in the other groups. In contrast, participants in the Nutri A group were expected to give generally lower ratings than the Control group. Finally, a behavioral intake measure was used to assess whether nutritional labels influenced actual consumption. We expected participants in the Nutri E condition to eat the fewest crisps in the final consumption test, consistent with enhanced satiety. In contrast, the Nutri A group was expected to consume the most, potentially compensating for the perceived lower caloric value.

4. Method

4.1. Participants

A power analysis identical to that of Experiment 1 was conducted using G*Power, specifying a repeated measures ANOVA with one within-subject factor (two levels) and one between-subject factor (three levels), $\alpha = 0.05$, power ($1 - \beta$) = 0.95, and $\varepsilon = 0.5$. For a medium effect size ($f = 0.25$), the analysis indicated a minimum required sample size of 66 participants. A total of 84 participants (71 female and 13 male) were recruited through the University of Granada's institutional platform. The mean age was 21.65 years ($SD = 5.4$; range: 18–51). All participants gave written informed consent and received academic credit in exchange for participation. Participants were randomly assigned to one of three experimental groups based on the nutritional label condition: Nutri E (High label), $N = 27$; Nutri A (Low label), $N = 28$; and Control, $N = 29$.

The exclusion criteria were the same as in Experiment 1. Fourteen participants were excluded from the final sample due to meeting exclusion criteria: 12 reported a history of eating disorders, and two had eaten within two hours prior to the session. After exclusions, the final sample consisted of 70 participants (60 female, 10 male; mean Body Mass Index = 22.8). The final N for each group condition was as follows: Nutri E (High label), $N = 24$; Nutri A (Low label), $N = 21$; Control, $N = 25$.

4.2. Apparatus and stimuli

Crisps from the ANIZVI brand were used as pre-feeding stimuli, with 72 g provided to each participant in two servings of 30 g and 42 g. The same bowl was utilized for both servings, and the crisps were weighed before and after each serving to measure intake. Participants were also offered unlimited water during the eating periods.

Nutritional labeling was based on the Nutri-Score system, which categorizes food from A (dark green, highest nutritional quality) to E (dark orange, lowest nutritional quality). This front-of-package system allows quick comparisons within a product category—ideal for this study, as all participants evaluated the same food (crisps). Nutri-Score was chosen because 1) It simplifies nutritional interpretation, 2) It facilitates comparisons within identical food categories, and 3) It was recently implemented in Spain, where this study was conducted.

A fictitious crisp brand was digitally created. Packaging included either a Nutri-Score A label (Low-Calorie label), a Nutri-Score E label (High-Calorie label), or no label (Control).

Four visual analogue scales (VAS), ranging from "Not at all" (0) to "Very much" (100), were used to assess the effect of the nutritional labels on participants' perceived physiological state and their evaluations of the crisps. These scales measured liking, wanting, and perceived satiating capacity of the crisps, along with participants' general hunger. Each scale was completed at three points during the experiment: before consuming the crisps, after the pre-feeing phase, and following the attentional task. Additionally, the same final evaluation scales used in Experiment 1 were applied here to assess participants' ratings of the attentional task stimuli. All scales were completed digitally using a computer and mouse.

The visual attention task used the same stimuli and setup as in Experiment 1, with the exception that TF images were excluded. This change was made to simplify the task and also because Sawada et al. (2019) found that the attentional capture effect following satiety manipulation was specific to FF images. The same equipment, including computers, screens, and keyboards, was used as in the previous experiment.

4.3. Procedure

Participants were asked to arrive in the same fasting state as in Experiment 1. Upon arrival at the laboratory, they completed the same questionnaire covering demographic data and general eating habits (including the first self-reported hunger measure). After this initial stage, all participants received the following information on the screen:

"*We are carrying out an experiment to study how a new brand of crisps is perceived. For this purpose, you will have to answer some questions about your experience and the style of their packaging. Your task during this test will be to:*

1. View the information presented about the product you will test.
2. Try the product and answer a series of questions about it.
3. Perform a simple computer task.
4. Answer a series of questionnaires".

Following this general introduction, participants were shown condition-specific content. Those in the Nutri A and Nutri E groups were presented with a fictitious crisp bag accompanied by the appropriate Nutri-Score label (A or E) and the following message:

"*This is the new brand of crisps you are going to try. On the right, you can see the prototype of the pack design that will be on sale soon. On the left you can see the nutritional information of this new product through the category it has been assigned in the Nutri-Score scale. If you don't know what the Nutri-Score system is, here you will learn more about it.*"

The next screen provided a brief explanation of the Nutri-Score system, detailing the 5-category system using a logo that includes a letter and a color ranging from A (dark green) to E (dark orange), with B (light green), C (yellow) and, D (orange) between them. It was explained that the A logo (dark green) indicates better nutritional quality, and the E logo (dark orange) indicates poor nutritional quality. The explanation also noted that the score is calculated based on the product's nutritional content per 100 g/100 ml, with certain nutrients and components contributing either favorable or unfavorable points—such as energy, sugars, saturated fats, and salt.

In the control group, participants were simply shown the fictitious packet of crisps without a nutritional label and were told that this was the new brand of crisps to be evaluated. All participants, regardless of condition, were then shown the crisp package again (with or without a label, depending on the group) and received the following instructions:

"*Please, we are now going to ask you to taste the sample of crisps that we are going to offer you. Please wait for the experimenter.*"

Each participant received a bite-size sample of crisps and completed three crisps rating scales: liking, expected satiation, and wanting. These ratings were completed individually after tasting the crisps. Participants were then given a 30-g serving of crisps and invited to eat as much as they wanted. During this consumption phase, participants in the labeled groups viewed the corresponding crisp packaging with its Nutri-Score label, while the control group saw only the unlabeled version. Finally, they completed the same three scales again, along with the hunger scale.

After completing the second round of ratings, the experimenter re-entered to provide instructions for the visual search task. This task was identical to that in Experiment 1, except that only two target categories were used—fast food (FF) and neutral objects (NE)—omitting traditional food images to simplify the design. Each target category appeared 16 times, for a total trial number matching that of the first experiment. Participants completed 20 practice trials—10 SAME and 10 DIF trials—prior to the main task.

Once the visual search task was finished, participants were given a second bowl of crisps, this time containing 42 g, and were again told to eat as much as they wanted. During this final consumption period, a screen displayed various prototype crisp packages. Participants were told they would evaluate the designs, a cover story intended to ensure uniform time spent eating across groups. After viewing the packages, they rated each one on a Likert scale from 0 ("nothing") to 10 ("very much"). Finally, they completed the same four VAS crisp evaluation scales used earlier, followed by the control scales and the dietary information questionnaire from Experiment 1. As before, the control ratings were included in the supplementary material. At the end of the session, the crisp bowl was collected, and the remaining contents were weighed to calculate total consumption.

4.4. Open access

All data, stimuli, and analyses of the present study are fully and freely available at the following link: https://osf.io/gucx4/?view_only=de50a87ae03c45a18446516937701bbf

4.5. Data analysis

The data preprocessing and analysis procedures for the attentional task followed the same steps as in Experiment 1. Outliers accounted for 6.53 % of the data. For each participant, mean response times (RTs) were calculated for each condition, yielding two RT scores per participant. Based on our prior hypothesis (FF < NE), RTs and error rates were submitted to a repeated-measures ANOVA (RM-ANOVA) with Condition (FF, NE) as a within-subject factor and Group (Nutri A, Nutri E, Control) as a between-subject factor. Where necessary, post-hoc comparisons were adjusted using Holm's correction to control for multiple comparisons.

5. Results

All participants confirmed that they had fasted for 2 h before the experiment. Reported fasting times were as follows: Nutri A: $M = 6.9$ h; Nutri E: $M = 5.6$; and Control: $M = 5.5$ ($F < 1$). No difference in consumption of crisps was found between the three groups in the pre-feeding phase, $F(2, 67) = 0.534$, $p = 0.588$, $\eta_p^2 = 0.02$ (Nutri A: $M = 22.6$, $SE = 1.6$; Nutri E: $M = 24.4$, $SE = 1.1$; Control: $M = 24.2$, $SE = 1.3$).

The main effect of Condition on RTs was significant, $F(1, 67) = 3.98$, $p = 0.050$, $\eta_p^2 = 0.06$. Participants responded faster in the FF condition ($M = 515$ ms, $SE = 6.1$) than in the NE condition ($M = 518$ ms, $SE = 6.3$). Neither the main effect of Group nor the interaction Group*Condition reached significance ($F < 1$) (see Fig. 3). This result replicates the attentional bias toward food stimuli by demonstrating faster detection of food stimuli over neutral stimuli (See Fig. 3). Error rate analysis also revealed a significant main effect of Condition, $F(1, 67) = 4.56$, $p = 0.036$, $\eta_p^2 = 0.06$. Participants committed fewer errors in the FF condition ($M = 4.20$ %, $SE = 0.4$) than in the NE condition ($M = 5.02$ %, $SE = 0.5$). Again, neither the main effect of Group nor the interaction Group*Condition reached significance ($F < 1$.

Ratings for Hunger, Liking, Wanting, and Expected Satiation were submitted to a Repeated-Measures ANOVA with Time (1,2,3) as a within-subject factor and Group (Nutri A, Nutri E, or Control) as the between-subject factor. Greenhouse-Geisser corrections were applied where necessary due to violations of sphericity. Analysis of Hunger ratings revealed a main effect of Time $F(1.73, 116.13) = 59.66$, $p < 0.001$, $\varepsilon = 0.87$, $\eta_p^2 = 0.47$. Neither the main effect of Group $F(2,67) = 2.38$, $p = 0.100$, $\eta_p^2 = 0.07$ or the interaction Time*Group $F(3.46, 116.13) = 0.44$, $p = 0.754$, $\varepsilon = 0.87$, $\eta_p^2 = 0.01$, reached significance. Post-hoc comparisons revealed significant differences between T1 ($M = 67.4$, $SE = 2.7$) and T2($M = 39.1$, $SE = 3.1$), $t(69) = 9.08$, $p < 0.001$, and between T1 and T3 ($M = 36.6$, $SE = 3.2$), $t(69) = 9.80$, $p < 0.001$. No differences were found between T2 and T3 $t < 1$ (See Fig. 4). These results confirm that hunger was significantly reduced following crisp consumption.

Analysis of the Liking ratings revealed a main effect of Time $F(1.64, 109.6) = 3.81$, $p = 0.025$, $\varepsilon = 0.82$, $\eta_p^2 = 0.05$. Neither the main effect of Group $F(2, 67) = 2.51$, $p = 0.089$, $\eta_p^2 = 0.07$ or the interaction Time*Group $F(3.28, 109.6) = 1.50$, $p = 0.216$, $\varepsilon = 0.82$, $\eta_p^2 = 0.04$, reached significance. Post-hoc comparisons indicated a near significant decrease from T1 ($M = 72.7$, $SE = 2.2$) to T2 ($M = 69.0$, $SE = 2.6$), $t(69) = 2.13$, $p = 0.070$, and a significant decrease from T1 to T3($M = 68.0$, $SE = 2.9$), $t(69) = 2.59$, $p = 0.032$. No differences were found between T2 and T3 $t < 1$ (See Fig. 4). These findings reflect a slight but consistent decline in liking ratings after consumption.

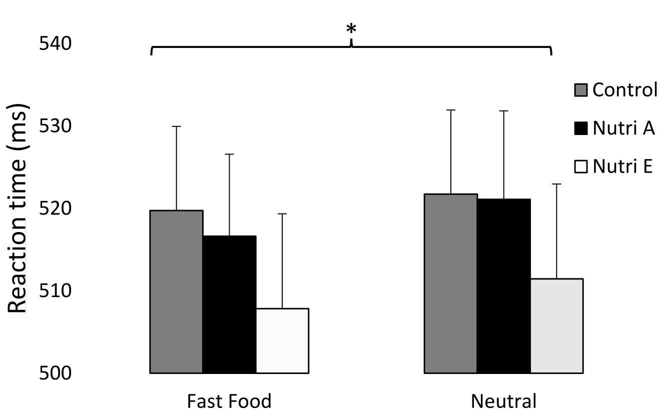

Fig. 3. Participants' performance on the visual search task.

Analysis of the Wanting ratings revealed only a significant main effect of Time $F(1.74, 116.90) = 27.50$, $p < 0.001$, $\varepsilon = 0.87$, $\eta_p^2 = 0.29$. The effects of Group $F(2, 67) = 1.69$, $p = 0.192$, $\eta_p^2 = 0.05$, and the Time*Group interaction, $F(3.49, 116.90) = 1.17$, $p = 0.325$, $\varepsilon = 0.87$, $\eta_p^2 = 0.03$, were not significant. Post-hoc test revealed a significant decline in wanting from T1 ($M = 69.1$, $SE = 2.9$) to T2 ($M = 50.2$, $SE = 3.2$), $t(69) = 6.02$, $p < 0.001$, and from T1 to T3 ($M = 47.9$, $SE = 3.2$), $t(69) = 6.76$, $p < 0.001$. No differences were found between T2 and T3 ($t < 1$; see Fig. 4). The observed patterns for both Liking and Wanting were expected and can be explained in terms of Sensory-Specific Satiation (e.g., González et al., 2022; Havermans et al., 2009; Rolls, 1986).

Analysis of Expected Satiation ratings revealed a significant main effect of Time $F(1.59, 106.81) = 24.97$, $p < 0.001$, $\varepsilon = 0.80$, $\eta_p^2 = 0.27$. Neither the main effect of Group $F(2, 67) = 0.72$, $p = 0.488$; $\eta_p^2 = 0.02$ nor the interaction $F(3.2, 106.81) = 0.30$, $p = 0.834$, $\varepsilon = 0.80$, $\eta_p^2 = 0.01$, reached significance. Post-hoc comparisons revealed significant increases in expected satiation from T1 ($M = 53.0$, $SE = 2.9$) to T2 ($M = 68.6$, $SE = 2.6$), $t(69) = -5.92$, $p < 0.001$ and from T1 to T3($M = 69.8$, $SE = 2.8$), $t(69) = -6.30$, $p < 0.001$. No differences were observed between T2 and T3 ($t < 1$; see Fig. 4). These results indicate that participants generally perceived crisps as more satiating after eating them.

Regarding the final intake test, no difference was found between the three groups in the quantity of crisps consumed, $F(2, 67) = 1.025$, $p = 0.365$, $\eta p^2 = 0.02$, (Nutri A: $M = 20.3$, $SE = 2.9$; Nutri E: $M = 21.2$, $SE = 2.0$; Control: $M = 24.8$, $SE = 2.2$).

6. Discussion

The main goal of the present experiments was to test whether Nutri-Score labels could alter participants' motivational states and influence food preferences and intake. Therefore, one aim was to explore food-related attentional bias as an implicit measure of motivational change following food consumption. In Experiment 1, we replicated the attentional bias reported by Sawada et al. (2017), using images of fast food, traditional food, and neutral items (tools) as visual search targets. Among hungry participants, we observed two key effects: (1) food images captured more attention than neutral images, and (2) fast food images attracted more attention than traditional food images. These results confirm the robustness of the attentional advantage for food stimuli in visual search tasks, showing that it persists even when the task differs in methodological details from previous studies (e.g., de Oca & Black, 2013; Nummenmaa et al., 2011; Sato, 2021). We also found that this attentional bias was modulated by the nutritional properties of the food images in a sample of hungry participants, consistent with earlier studies (e.g., Sawada et al., 2017, 2019).

Some studies, however, have found no evidence for a facilitation effect of food images in visual search tasks (e.g., de Oca & Black, 2013; Nummenmaa et al., 2011). For instance, de Oca and Black (2013) reported that food images were detected more quickly than some neutral stimuli (e.g., flowers) but not others (e.g., chairs). There are notable procedural differences between our study and those that failed to find attentional bias effects. For example, de Oca and Black (2013) task used a five-item search array, compared to our four-item array, potentially increasing task difficulty. Furthermore, their target images were not controlled for perceptual features such as white balance, brightness, and RGB values. In their study, these perceptual properties were standardized by presenting images in greyscale. This is important, as prior work suggests that color plays a key role in the rapid recognition and detection of food stimuli (Sato, 2021). This raises the question of whether the attentional bias effect is color-dependent and perhaps driven by perceptual salience (a "pop-out" effect) rather than motivational relevance. However, the fact that the effect is modulated by factors such as energy content and participants' hunger levels supports the idea that it is guided more by the motivational and hedonic value of food than by its perceptual features. Furhermore, Nummenmaa et al. (2011) also reported a different pattern of results. In their first experiment, food

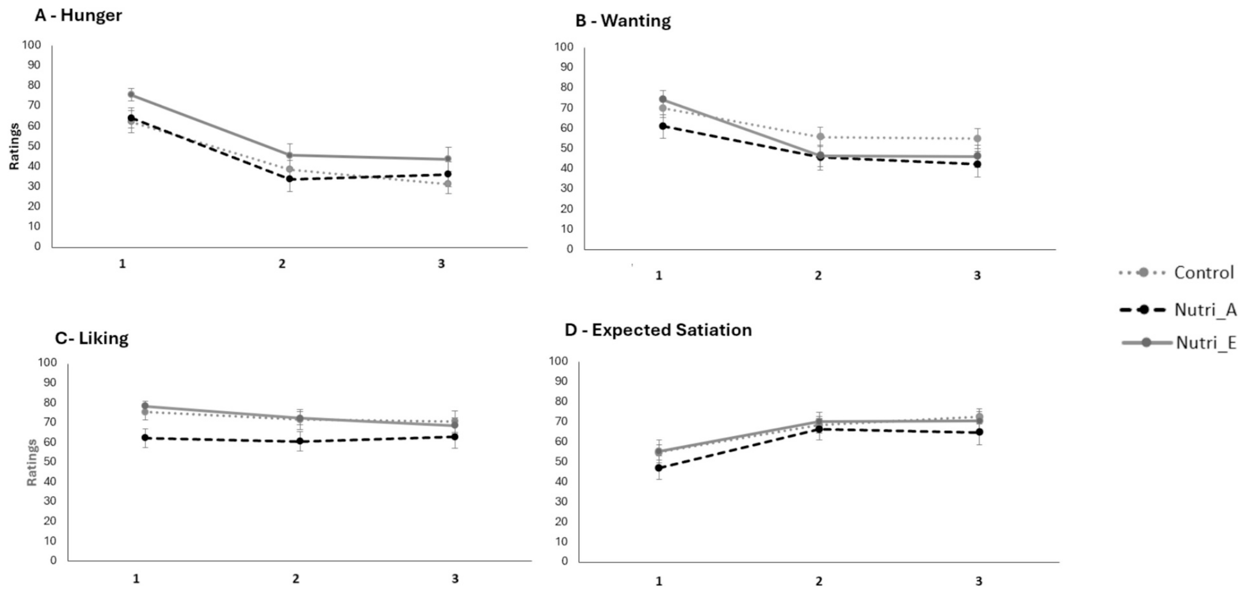

Fig. 4. Crisp Ratings by group: Hunger, Wanting, Liking, and Expected Satiation.

images were detected more quickly than neutral stimuli such as cars. However, this effect disappeared when the neutral stimuli were replaced with perceptually similar objects to the target food (e.g., a green apple and a tennis ball). This could be due to increased task difficulty from a more complex stimulus matrix, but it may also indicate a generalization process. Participants may respond to a perceptually similar neutral stimulus as if it were motivationally relevant despite its lack of actual motivational value.

Having established the basic attentional capture of food images in Experiment 1, Experiment 2 replicated this result: Participants showed faster detection of food images than neutral ones. However, regarding the impact of nutritional labels, we found no differences between the three groups after they consumed the labeled crisps. That is, nutritional labels did not affect attentional capture. This lack of difference suggests that the labels were ineffective in modulating participants' motivational states. Supporting this, subjective hunger ratings also showed no significant differences between the groups. Therefore, our results provide no evidence that nutritional labels influence motivational states—either explicitly (via self-report) or implicitly (via attention). As expected, participants reported lower hunger after eating the crisps, confirming that the pre-feeding manipulation successfully altered their motivational state. However, the nutritional labels did not "mimic" the effects seen in Flavor-Nutrient Learning. All three groups gave similar ratings for the crisps' hedonic appeal, motivational value, and satiating properties. If this had occurred, we would expect those who consumed crisps with a high-calorie label to rate them as more palatable, appetizing, and filling. Since no such pattern emerged, it appears that nutritional labels did not alter the hedonic value, motivational significance, or expected satiation of the food. Finally, the absence of any label-driven effect on participants' motivational state is consistent with the ad libitum consumption test results, where no differences were found in intake between the groups. This finding does not support the idea of intake compensation (similar to conditioned satiety), at least with the procedures used in this study.

Our results suggest that nutritional labels do not support explicit food-calorie learning, as they fail to alter motivational state, liking, or intake. Despite methodological differences, this pattern of results is consistent with those reported by Gould et al. (2018), who found that calorie information provided by nutritional labels not only fails to facilitate flavor-nutrient learning but may actually interfere with it. In their study, participants were exposed to a target food over four consecutive days, creating optimal conditions for both explicit learning from labels and implicit learning through nutrient feedback. Although they used a different labeling system and assessed behavioral change through measures such as liking, intake, and satiety expectations—rather than attentional bias—their findings similarly showed no supportive role for calorie labeling in enhancing food-related learning. A promising direction for future research would be to design a similar multi-session learning experiment where participants repeatedly consume nutritionally labeled foods. This approach could clarify how explicit label-based knowledge interacts with implicit flavor-nutrient learning while also offering a more ecologically valid view of how nutritional labels influence appetite, preferences, and consumption.

Several caveats must be acknowledged. The lack of modulation by nutritional labels observed in the present study may be due, in part, to limitations in the experimental design that reduced sensitivity to detect group differences. First, participants may have interpreted information from the nutritional labels beyond calorie content. For instance, those exposed to the E label may have perceived the crisps not only as more caloric but also as less healthy compared to other groups. This perception could have negatively influenced subjective liking and wanting ratings, potentially counteracting any positive effects of calorie-based expectations. Second, while the 30 g portion of crisps was sufficient to induce a subjective motivational change (i.e., reduced hunger), it may not have been strong enough to elicit measurable differences in the visual search task across groups. Supporting this, the food-related attentional bias persisted in all groups after the satiety manipulation, indicating that the target foods remained attractive even after eating. Furthermore, the use of fast food images in Experiment 2—known for their high hedonic and motivational value—may have made the stimuli more resistant to satiety effects, further limiting the sensitivity of the design.

To improve sensitivity, future studies could align the food stimuli used in the visual search task with those used during the learning phase, where foods are paired with specific nutritional labels. This consistency might strengthen the link between the label and the implicit motivational response measured in the task. Lastly, the sample size in Experiment 2 may also be a limiting factor. Although a priori power analysis using G*Power (Faul et al., 2007) was conducted to determine the minimum required sample size, the effect under investigation may be smaller than anticipated. As such, detecting meaningful group differences may require a larger sample size to adequately capture subtle effects.

An important consideration for future research is the potential *negative* impact of nutritional labels on food intake. It is well-established that Pavlovian cues signaling the presence of highly caloric and palatable foods—such as advertisements, smells, or images—can trigger a range of appetitive responses that often lead to increased consumption (for reviews, see Jansen et al., 2015; van den Akker et al., 2018; Kanoski & Boutelle, 2022). These responses, collectively known as Food Cue Reactivity, are evolutionarily adaptive, preparing the organism for ingestion (Schyns et al., 2020). However, in modern environments where high-calorie foods are readily available, and lifestyles tend to be sedentary, these responses may contribute to overeating (Johnson, 2013). Excessive cue reactivity has been linked to increased intake and has been observed to be stronger in individuals with overweight or obesity (e.g., Boswell & Kober, 2016; Jansen et al., 2003). Studies using paradigms like Cue-Potentiated Feeding further show that food-paired cues can prompt eating even when individuals are physiologically sated (e.g., Reppucci & Petrovich, 2012; Weingarten, 1983; Kendig & Corbit, 2024). This raises a critical concern: Nutritional labels, especially those denoting high-calorie content, could themselves become appetitive cues. Rather than acting as deterrents to promote responsible consumption, these labels might acquire motivational properties that increase the likelihood of future intake—particularly in hungry states. Instead of reducing consumption, exposure to such labels could paradoxically promote the selection of less desirable foods. Combined with flavor-nutrient learning—which strengthens the preferences of foods paired with positive post-ingestive effects—this could lead to unintended consequences. Labels might increase the value of certain foods over time, promoting rather than discouraging their consumption.

The study of nutrition labeling has received increasing attention in recent decades (e.g., Zlatevska et al., 2024). In response to rapidly rising global rates of obesity and overweight, these labels have been proposed as a potential prevention and intervention strategy (Hercberg et al., 2021; Temple, 2020). Since excessive food intake and resulting energy imbalance are major contributors to obesity, labeling systems aim to support healthier food choices (e.g., selecting lower-calorie or more nutritious options) by making nutritional information more accessible to consumers (van den Akker et al., 2022). For instance, an increasing number of countries have implemented nutritional labeling on restaurant menus, with evidence showing reductions in calorie consumption following such interventions (e.g., Crockett et al., 2018; Roseman et al., 2017). Other studies have examined how labeling on supermarket products influences dietary habits and purchase behavior (e.g., van den Akker et al., 2022; Julia et al., 2016; for a systematic review, see An et al., 2021). Indeed, extensive research in this area has contributed to a shift in global food labeling standards (Temple, 2020). Until a few years ago, labels appeared on the back of packaging (Back-of-Package Labels), often in numeric formats that were not user-friendly. In contrast, Front-of-Package (FOP) labels were developed to present nutritional information in a more visual and intuitive format, improving consumer comprehension. The World Health Organization (WHO, 2017, 2024) has since recognized FOP labeling as a key public health policy to combat the global obesity crisis.

Several types of FOP labels are currently in use. Temple (2020) categorizes them into two main groups: *specific labels*, which provide detailed information about individual nutritional components, and *summary labels*, which offer a single overall rating of the product's nutritional quality. The latter includes the Nutri-Score system used in the present study. Nutri-Score aims to simplify consumer decision-making by enabling easy comparisons within a single food category—for example, helping consumers choose a lower-fat crisps brand over a higher-calorie alternative (Hercberg et al., 2021; Merz et al., 2024). Originally proposed in France (Hercberg et al., 2014), Nutri-Score has only recently been adopted in various EU countries. In Spain, for instance, it was introduced in 2021, though implementation remains voluntary (Merz et al., 2024). Given its relatively recent adoption, it may still be too early to draw firm conclusions about its real-world effectiveness in influencing food choices or improving health outcomes (Peters & Verhagen, 2024). Although the label's design is intended to guide consumers toward more nutritionally favorable choices, there is a risk of misinterpretation. For example, a product classified with a certain Nutri-Score letter might be seen as "recommended" or "healthy" simply because it carries a label, regardless of the broader dietary context (Hercberg et al., 2021). Such misinterpretations may be more likely in populations still unfamiliar with the system—an important factor to consider in studies assessing its impact. However, this could not explain the lack of effect of the nutritional labels in our study. If anything, such factors would be expected to enhance group differences —not eliminate them.

In conclusion, the present results are inconclusive regarding the role of nutrition labels in modulating perceived physiological states. We also found no evidence that such labels influence the satiating capacity or the perceived hedonic and motivational value of the foods to which they are attached. Future research should consider increasing the strength of the satiety manipulation during the pre-feeding phase and exploring the effects of other types of Front-of-Package labels. A promising design would involve incorporating a learning phase in which foods from the same category (e.g., various types of cheese) are paired with different caloric values via nutritional labels. This would allow researchers to assess whether foods associated with specific nutritional profiles produce differential effects on attentional processes, as measured by performance in a visual search task—similar to the facilitation effects observed in Experiment 1 of the present study.

Author note

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CRediT authorship contribution statement

Ana González: Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Fernando Ojedo:** Writing – review & editing, Writing – original draft, Software, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Irene Ruiz:** Writing – original draft, Methodology, Investigation, Formal analysis. **Isabel de Brugada:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Ethical statement

Ethical approval for the involvement of human subjects in this study was granted by Ethics Committee at the University of Granada (Number issued by the Ethical Committee: 2246/CEIH/2021.

Author statement

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data availability

The effect of nutritional labels on the facilitation of food picture detection (Original data) (OSF)

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