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Role of Nutri-Score and Eco-Score in shaping consumers' sensory expectations and purchase intention: An eye-tracking study on animal- and plant-based foods

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ABSTRACT

Objective: Front-of-package (FOP) labeling schemes could be adopted to provide consumers with timely and credible information and to promote healthy and sustainable food consumption. In addition, when defining healthy and sustainable food behaviors, international authorities agree that reducing meat consumption could be of benefit to both human health and the planet. Given the increasing interest in plant-based meat alternatives (PBMAs) and FOP labels, we investigate in this study how interpretative FOP labels—the Nutri Score (NS) and Eco Score (ES)—impact consumers' sensory expectations and purchase intention of a meat product and its plant-based counterpart.

Method: Using eye-tracking data, we analyzed whether and to what extent attention to these labels affects participants' behaviors (n = 76). In addition, to explore differences across consumer segments we divided our sample based on the Meat Attachment Questionnaire (MAQ) to classify subjects according to their bond towards meat consumption.

Results: Results showed that attention to the NS or ES did not impact participants with higher MAQ scores (i.e., with a more positive bond toward meat consumption); however, sensory expectations of both the meat and plant-based product were influenced by consumer visual attention for participants with a lower meat attachment level (i.e., with lower MAQ scores). Specifically, we found a positive relationship between the attention paid to the positive ES of the plant-based product and the expectation of liking it (abreviated as "expected liking"), and a positive interaction between the attention paid to the negative NS of the animal product and its expected liking.

Conclusions: We show that favorable sustainable labels can positively shape consumers' expectations for PBMAs, while negative labels do not undermine expected liking or purchase intention for animal products, and discuss our results to provide insights for future research and implications for both food industries and policymakers.

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Introduction

Nowadays, many governmental and international institutions are looking for effective strategies that could steer consumers' food purchase and consumption decisions toward more sustainable and healthier choices [1,2]. Reducing greenhouse gas (GHG) emissions while preserving individuals' health has become a top priority over the last few years, and providing consumers with the right tools to make informed and timely choices is a recognized strategy to mitigate the impact of the food system on both our health and the planet [3].

Many countries already have mandatory nutrition information on the back of food packages ([4] [EU] No 1169/2011, 2011); however, the World Health Organization (WHO) also recommends mandatory front-of-package (FOP) labeling schemes to promote healthy and sustainable diets and stress the importance of visible information on the nutritional value of food products, as well as information on their environmental impact [5,6]. Although previous studies support the adoption of mandatory FOP policies to steer consumers' choices and to encourage the food industry to reformulate its products, few countries have adopted labeling systems, either on a mandatory or voluntary basis [7,8]. Thus, research on this topic remains critical to guide policymakers in choosing the most appropriate FOP to adopt [3]. Following this line, the European Commission also proposed a harmonized mandatory FOP labeling scheme to be adopted in the European Union [9,10].

Several classifications of FOP labels exist [11]. Among these, a common method to classify FOP labels is to divide them into

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interpretative and noninterpretative labels [8]. The first category includes symbols and figures that "advise" consumers by providing healthfulness/sustainability information on the product (e.g., traffic-light labels). On the other hand, noninterpretative FOP labels (e.g., reference intake labels) provide a summary of specific nutritional or environmental aspects [12,8]. Previous research agrees that interpretative FOP labels can be an effective tool to assist consumers in their daily decisions by avoiding information overload [13,8,14,6]. In addition, to ensure that both health- and sustainability-related aspects are conveyed on the FOP labels, the concept of an interpretative dual labeling scheme—where both nutrition and sustainable labels are present—has been proposed [15]. Although the literature on the topic is still scarce [15–17], combining interpretative FOP labels on nutrition and sustainable aspects has shown promising results in prompting consumers' food choices ([15]; Osman & Thornton, 2019).

One recently developed interpretative FOP scheme is the Nutri-Score (NS) label, a nutrition label that provides a simple and complementary indication of the overall nutritional quality of food products overall nutritional quality by using a rating system that conveys the "indication of use" [11,18]. The NS summarizes the nutritional profile of a product through a five-category scale, ranging from A (dark green) to E (red), where A indicates products with the highest nutritional quality and E suggests those with the lowest. The classification is based on a scientific algorithm derived from the UK Food Standards Agency nutrient profiling system, which balances nutrients and foods to favor (e.g., fiber, protein, fruits, vegetables, legumes, nuts, and certain oils) against those to limit (e.g., energy, saturated fats, sugars, sodium) [19,20]. The NS was first implemented in France in 2017 in response to the French Ministry of Health's willingness to create a FOP nutrition labeling system to facilitate consumers' food choices [18]. Since then, other European countries have adopted this system on a voluntary basis (e.g., Belgium, Spain, and Germany), while others are challenging its adoption, such as Czech Republic, Cyprus, Greece, Italy, Latvia, Romania, and Hungary [21–23].

More recently, an interpretative FOP system—the Eco-Score (ES)—resembling the NS format has also been developed to underscore the sustainable dimension of food products [24]. The ES was introduced in France in 2021 as a voluntary environmental front-of-pack (FOP) label to help consumers make more informed and sustainable food choices. Similar to the NS, the ES is a food label that ranges from A ("the most sustainable option") to E ("the least sustainable option") and from green to red. The ES gives an overall evaluation of a food product's environmental impact, and, in its algorithm, it incorporates the Life Cycle Assessment (LCA) from the Agribalyse database with additional environmental-related factors, such as production and transportation, packaging, country of origin of ingredients, and the seasonality of the finished product [24]. It also applies bonuses and penalties based on criteria such as certifications or sourcing practices to refine the final score [15]. Although the ES is not yet mandatory, it has gained growing visibility through its adoption by several retailers in France, and, more recently, in Germany [25]; however, little research is currently available on the effects of this FOP label on consumers' choices [26]. An image of the NS and ES is reported in Figure 1.

In this context, the present study aims at expanding the scientific literature on the topic of FOP labeling schemes and testing the impact of a dual labeling scheme (i.e., when both the NS and ES are displayed on the front of the food package) on consumers' sensory expectation and purchasing behaviors. To do so, this study moves beyond consumers' self-reported measures by merging these data with participants' visual attention. Specifically, eye-tracking data were employed to evaluate consumers' attention to the FOP labels and explore the relationship that this has on individuals' purchase intentions and product expectations.

In addition, given that the main objective of an FOP system is to provide consumers—especially those who do not have in-depth knowledge of nutrition and sustainability aspects—with an intuitive and easily accessible tool to make informed food purchases, we decided to test the dual labeling scheme on a population who is not familiar with the proposed labels. Because the investigated labeling schemes were developed in France and are currently adopted in some European countries only, we deliberately focused our research on North American consumers to examine how unfamiliar, interpretative labeling schemes influence consumer



Fig. 1. (A) the Nutri-Score, and (B) the Eco-Score.

expectations and purchasing intentions in a context where prior exposure is low or absent. Studying a population that is largely unfamiliar with NS and ES allows us to better isolate the effect of the labels themselves, rather than preexisting associations or familiarity effects.

Background and hypotheses

While research on eye-tracking and FOP labels is increasing, to the best of our knowledge, studies measuring consumer attention to the NS or ES using eye-tracking methodologies are still scarce. Few authors have investigated visual attention to the NS [27,28] and we could find no study using eye-tracking to explore visual attention to the ES or evaluating its relationship with consumers' behaviors and choices. Bossuyt et al. [27], for instance, investigated the association of visual attention to the accuracy of healthfulness evaluation when displaying the NS, the Nutrition Facts Panel, or both. The authors found a lower average error in the estimation task for participants who paid more visual attention to the NS. In another study, Gabor et al. [28] used eye-tracking to analyze consumers' visual attention to food packaging with different FOP nutrition labels. The most accurate healthfulness estimates were linked to the Guideline Daily Amounts label; however, the NS required the least time to process the information. In sum, few studies on the relationship between attention to interpretative FOP labels and consumer behavioral intention currently exist.

Moreover, previous research has shown that greater visual attention to product information or labels is generally associated with more favorable evaluations, including higher product liking and WTP [29,30]. Visual attention reflects the cognitive processing of stimuli, and when consumers pay more gaze time to a specific product cue (such as a nutrition or sustainability label or claim), it has been associated with higher choice likelihood. Conversely, limited attention or visual avoidance tends to be associated with lower liking or a reduced likelihood of choice [31–33]. This evidence suggests that attention allocation can be used as a proxy for consumers' underlying preferences and decision-making processes, thereby supporting the rationale behind our hypotheses.

In addition, to evaluate the adoption of FOP labels, it is necessary to assess their effects on consumers' choices when displayed for critical food categories, such as red meat. Specifically, red meat is associated with a higher risk of noncommunicable diseases, such as cardiovascular diseases [5]. Additionally, red meat production poses significant challenges also to environmental sustainability [34,35]. The risks associated with red meat consumption in general have led to the development and production of plant-based meat alternatives (PBMAs)—i.e., foods that recall meat products (e.g., burgers or sausages) but are made with plant-based ingredients (e.g., soy, wheat, pulses, etc.) [36]. Indeed, promoting PBMAs could potentially improve consumers' health and increase the sustainability of their food choices by leading to reduced red meat consumption [37]. In terms of nutritional differences, studies showed that PBMAs mostly have lower energy and total and saturated fat content. Concerning sustainable aspects—despite methodological limitations in the assessment process—the few resources required per product unit of PBMAs represent a promising opportunity to decrease the environmental impact of meat consumption [38]. In this context, we developed 2 hypotheses to explore the impact of a dual NS-ES scheme on consumers' purchasing intention and sensory expectation of a PBMA and its animal counterpart. Given the low number of studies on pork meat substitutes [39] and the projection of an increasing frankfurter consumption pattern in the US [40], we focused our research on traditional pork hot dogs and their plant-based version. The hypotheses follow the direction of research evaluating the role of color-coded FOP labels, which shows that—in line with the scope of these labels—the red color negatively affects consumers' purchase intention, while the green color is associated with more positive purchasing behaviors [16,26,41]. The following hypotheses are thus drawn:

H1: A higher visual attention to the positive NS and ES of a PBMA results in a higher willingness to buy and expected liking for the product.

H2: A higher visual attention to the negative NS and ES of a traditional meat product results in a lower willingness to buy and expected liking for the product.

To test these hypotheses, we combined eye-tracking data with self-reported measures of expected liking and willingness to purchase to investigate how much time consumers spent looking at each label and to define whether attention is associated with their purchasing intention and sensory expectations. Additionally, FOP labels can have different effects based on individuals' characteristics [42]. Because we tested the role that interpretative labels can have when prompting consumers to reduce meat consumption and since past research showed an interaction between consumers' positive or negative bond towards meat consumption and how meat alternatives are perceived [43], we segmented our sample based on participants' hedonistic attachment to meat. Finally, results from this research could be of help to policymakers and industries involved in food labeling and PBMA production to develop and implement effective tools to foster healthy and sustainable food choices among consumers.

Methodology

Consumers were recruited from the city of Ithaca (NY, the US) via emails and flyers and a total of 76 adults took part in the study. To participate, consumers had to: 1) be more than 18 years old, 2) be nonvegans/vegetarians, 3) have purchased wieners/frankfurters/sausages/hot dogs at least once over the six months prior to the study; 4) have normal or corrected-to-normal eye vision; and 5) have no allergies/restrictions to soy and pork. Data collection was conducted between October and November 2023 at the Eye Tracking Laboratory of the Dyson School of Applied Economics and Management, Cornell University. The study was granted ethical approval by Cornell's Institutional Review Board for Human Participant Research (Protocol number: IRB0147823).

Study procedure

The experiment was performed individually, and each participant provided informed consent before the study. Upon their arrival, participants were introduced to the study and were asked to read the definitions of the following terms: front-of-pack label, Nutri-Score, Eco-Score, and plant-based food. The same definitions were presented to each participant and can be found in the Appendix (Table A1). After reading these descriptions, the experiment began with an individual calibration for the eye-tracking device, which was performed by the investigator using a 9-point calibration method. The eye-tracking employed in this study was the chin and forehead rest Eye-link Plus 1000 (https://www.sr-research.com/eyelink-1000-plus/). After the calibration, participants were randomly shown the image of either a plant-based or a pork hot dog packaging on a computer screen (no minimum or maximum time was given to participants to observe the image in order to capture a

naturalistic behavior, allowing participants to observe the image for as long as they wished). The packaging information included the hot dog composition (i.e., "Plant-based hot dog" or "Pork hot dog"), and the NS and ES labels of the product. The NS and ES values were assigned considering their average values for plant-based ("A" for the NS and a "B" for the ES) and pork hot dogs ("E" for the NS and "D" for the ES). The same product image was used for both product types, with only the textual information ("Plant-based hot dog" or "Pork hot dog") and FOP labels varying between conditions. Following also a similar approach used in previous works (e.g., [44,45]), this design choice was made intentionally to isolate the effect of FOP labeling and product type information on consumer expectations and visual attention, while controlling for potential confounding effects related to product appearance (e.g., differences in color, shape, or packaging design). The images used in the study are displayed in the Appendix (Figure A1).

After observing the first image (either a plant-based or a pork hot dog), subjects were asked to rate their willingness to buy (WTB) the product from 1 (Definitely would not buy) to 7 (Definitely would buy) and their expected liking on a 9-point scale (from 1 = dislike extremely to 9 = like extremely). After the assessment of the first product, participants were shown the second image (if the plant-based hot dog was displayed first, they were shown the pork hot dog, and vice versa) and asked the same questions to investigate their WTB and expected liking.

Additional questions included in the experiment were sociodemographic questions (i.e., age, gender, education level, employment status, familiarity with the FOP labels ("Before participating in this study, had you ever seen this front-of-pack nutrition/sustainable label?"), and meat consumption frequency) and attitudinal questions. For the latter, we investigated participants' hedonistic attachment to meat using the hedonism subscale of the Meat Attachment Questionnaire (h-MAQ) [46]. We selected only the hedonism subscale rather than the full MAQ since our study focused on the affective dimension of meat attachment, rather than its social or dependency aspects. This subscale evaluates the pleasure and enjoyment derived from eating meat and is comprised of 4 statements (i.e., "To eat meat is one of the good pleasures in life," "I love meals with meat," "A good steak is without comparison," and "I'm a big fan of meat") with responses ranging from 1 (strongly disagree) to 5 (strongly agree). Finally, three subdimensions of consumers' subjective understanding of the labels were investigated using multiitem Likert scales derived from previous literature [47,48]: 1) comprehensibility (I feel well informed by this label; This label is believable and trustworthy; This label is easy to interpret); 2) help to shop (This label helps me to understand the product comparison; This label helps me to understand different nutritional (sustainable) values; This label makes it easier to choose food); 3) complexity reduction (This front-of-pack food label is rather extensive; Using this front-of-pack food label to choose food is better than just relying on my own knowledge about what is in them). Responses ranged from 1 (strongly disagree) to 5 (strongly agree).

Eye tracking

Eye tracking was used to support the investigation of whether consumers visually pay attention to certain elements and how these impact their behaviors [49,50]. For both images shown to participants, specific areas of interest (AOIs) were defined. AOIs are important areas of the image, and, in our study, these corresponded to the two labels under investigation: the NS and the ES. For the two AOIs of both images, total visit durations were calculated, which can be considered a proxy for visual attention [33]. The total visit duration for an AOI can be defined as the sum of the single visit durations of that AOI, where a visit duration is the time passed between the first and the last fixation, with no fixation outside that AOI—in other words, this is the sum of all fixations falling within an AOI [33,51]. Fixation counts are often used in consumer studies since information acquisition occurs during fixations [52].

Analysis

Analyses were performed using R Statistical Software, version 4.2.3 [53], with tidyr [54], dplyr [55], eyelinkReader [56], psych [57], GPArotation [58], lme4 [59], lmerTest [60], emmeans [61], performance [62], sjPlot [63], and lavaan [64] package. Descriptive statistics were used to analyze the sample characteristics and explore eye-tracking data. To identify consumer segments based on their pleasure and enjoyment derived from eating meat (h-MAQ), a two-step cluster analysis was performed by using the eigenvalues for the hierarchical Ward's method and the obtained centroids were used for a nonhierarchical K-means clustering. Differences across groups were tested using Chi-squares for gender, education, employment status, and familiarity with the FOP labels, Mann−Whitney for consumption frequency, and a t-test for age. In addition, t-tests were conducted to investigate differences in the subjective understanding of each label; whereas, and two-way ANOVAs were used to explore differences in the visual attention each cluster paid to each AOI by image. Finally, a series of mixed-effect models were performed to explore whether the visual attention to the labels had an impact on the dependent variables, i.e., participants' expected liking and WTB for both hot dogs. To control for interpersonal differences, visual attention was considered as the average relative fixation duration for both AOIs, i.e., the share of total time spent in each AOI (the NS or ES) out of the total time spent looking at each image. In addition, an interaction effect between the product (plant-based versus pork hot dog) and the independent variable (the average relative fixation duration) was considered in the models, which were conducted separately by product and by cluster.

Results

Two clusters were identified based on the respondents' meat attachment level (h-MAQ Cronbach alpha = 0.8). Specifically, respondents in cluster 1 (consumers with a Higher emotional Attachment to Meat for enjoyment—HAM, n = 44) showed higher scores for the hedonism dimension of the MAQ (h-MAQ: 4.01 $\pm$ 0.58), whereas cluster 2 (consumers with a Lower emotional Attachment to Meat for enjoyment—LAM, n = 32) had lower scores (h-MAQ: 2.76 $\pm$ 0.65). When investigating differences between groups, no differences were highlighted in terms of gender, age, education level, employment status, familiarity with the proposed labels, and meat consumption frequency. The main socio-demographic information by cluster is reported in Table 1.

Moreover, cluster differences in visual attention were investigated by comparing the average relative fixation duration of each AOI, per image. For the plant-based hot dog image, the two clusters differed in the total visit duration (expressed in seconds) of the ES ($P < 0.001$), with LAM consumers reporting a higher visit duration for this label than the HAM group. Moreover, significant differences were found within HAM consumers in the time allocated to the two AOIs, with the ES being attended the most. Concerning the pork hot dog image, no major differences were found either between or within clusters. Results from visit durations are reported in Table 2.

Table 1
Descriptive characteristics of the sample divided by cluster

	HAM N = 44	LAM N = 32	*P-value*
Gender[*]			
Female	27	25	
Male	15	7	0.298
Other	2	0	
Age mean (±SD)[†]	31.9 (±13.1)	33.3 (±14.4)	0.661
Education level[*]			
High school	3	5	
Bachelor's degree	17	15	0.274
Postgraduate (e.g., Master, PhD)	24	12	
Employment status[*]			
Full-time employment	15	11	
Part-time employment	4	2	
Unemployed	1	0	0.939
Retired	1	1	
Student	23	17	
Other	0	1	
Meat consumption frequency[‡]			
Never	0	0	
Rarely (up to one time a month)	16	16	
Occasionally (once-twice a month)	22	14	0.174
Sometimes (about once a week)	5	2	
Often (two-three times a week)	1	y	
Familiarity with the Nutri-Score[*]			
Yes	3	6	0.180
y	41	26	
Familiarity with the Eco-Score[*]			
Yes	2	2	1
No	42	30	

HAM, consumers with a Higher emotional Attachment to Meat for enjoyment; LAM, consumers with a Lower emotional Attachment to Meat for enjoyment.
[*]Pearson Chi-square
[†]t-test
[‡]Mann-Whitney test.

Table 2
Visit duration (in s) per image and AOI, divided by cluster.

AOI	Average relative fixation duration			
	Plant-based hot dog		Pork hot dog	
	HAM	LAM	HAM	LAM
Nutri-Score	28.1 (9.0) [a, X]	29.5 (8.9) [a, X]	31.0 (7.8) [a, X]	30.6 (9.6) [a, X]
Eco-Score	28.5 (9.1) [a, X]	36.1 (10.6) [b, Y]	30.8 (8.6) [a, X]	31.8 (11.9) [a, X]

HAM, consumers with a Higher emotional Attachment to Meat for enjoyment; LAM, consumers with a Lower emotional Attachment to Meat for enjoyment.
Standard deviation is reported in parentheses. Different lowercase letters within a row denote visit durations with significant differences ($P < 0.001$) between clusters, within each image. Different uppercase letters within a column denote visit durations with significant differences ($P < 0.01$) within the cluster, within each image.

Mixed-effect models

Table 3 represents the estimated marginal trend of the mixed models. To answer the hypotheses, we used mixed models with an interaction effect between the plant-based (H1) or the pork (H2) hot dog and the average relative fixation duration of the ES and NS. Results show no impact of visual attention on HAM participants—i.e., consumers who had higher h-MAQ scores and, thus who had a more positive bond towards meat consumption. Nonetheless, the estimate directions of the models are aligned with the hypotheses for the ES only. When focusing on the visual attention to the NS, the model shows a positive estimate direction for consumers' expected liking and WTB for the pork hot dog, despite its negative NS. In addition, a negative estimate value is identified for participants' WTB when considering the time spent looking at the NS of the plant-based product.

For LAM consumers (i.e., participants who had lower h-MAQ scores and, thus who had a more negative bond towards meat consumption, specifically for hedonistic aspects), the estimate directions follow the hypotheses, with a tendency of the visual attention to the ES of the plant-based hot dog positively influencing its expected liking. However, one result contrasts H2; specifically, higher visual attention to the negative NS of the pork hot dog had a significant positive effect on consumers' expected liking for the product.

Subjective understanding of the labels

To analyze consumers' subjective understanding of the NS and ES, three subdimensions were investigated: comprehension, help to shop, and complexity reduction.

The ANOVA analysis showed no significant differences between clusters in any of the three subdimensions. Specifically, the three items on comprehensibility, which measured the ability to easily interpret the label, were positive for the NS and ES, with the "This label is easy to interpret" item receiving the most positive score for both labels. In terms of help to shop, the item obtaining the lowest score was "This label helps me to understand the product composition" in both cases; whereas "This label helps me to understand different sustainable values" received the highest score for the ES and "This label makes it easier to choose food" received the highest value for the NS. For the two items investigating complexity reduction, both labels received lower scores for the "This front-of-pack food label is rather extensive" item—which is also in line with the idea of interpretative labels, which describe the product's features and aspects without providing many details.

Finally, results on consumers' subjective understanding showed an overall positive evaluation of the two labels, with minor discrepancies in the support provided in understanding the product composition and the labels being extensive. Means values of the three subdimensions are reported in Table 4.

Discussion

The present work aimed at analyzing the effects of visual attention to interpretative FOP labels (i.e., the NS and ES) on consumers' expected liking and purchasing intention. The few previous studies investigating whether the NS impacts consumers' taste perception of food products found no major influence of this labeling system [65,66]; however, none of these studies focused on meat and PBMAs. Therefore, our research investigated the association of consumers' visual attention to the NS and ES on their purchase intentions and product expectations for a plant-based and a pork hot dog. To do so, we combined self-reported measures with eye-tracking data to capture participants' attention to the two labels under investigation. Since FOP labels can have different effects based on individual characteristics, as suggested by Godden et al. [42], we segmented our sample based on consumers' attitudinal factors, as previously done in other studies [43,67]. Given that our study focused on expected liking and WTB for an animal product and its plant-based counterpart, we clustered our sample based on participants' hedonistic attachment to meat, measured by the hedonism subscale of the Meat Attachment Questionnaire (h-MAQ), which assesses the pleasure and enjoyment derived from eating meat.

Results showed interesting patterns in terms of visual attention for LAM participants (i.e., consumers with a lower emotional attachment to meat for enjoyment). Specifically, no statistically

Table 3
Estimated marginal trends of the mixed-effect models

	HAM			LAM		
	Estimate	SE	Marginal R2	Estimate	SE	Marginal R2
Exp_liking_NS_pork	0.014	0.037	0.004	**0.076****	0.033	0.148
Exp_liking_NS_plant	0.006	0.033		0.045	0.036	
Exp_liking_ES_pork	−0.009	0.033	0.013	−0.033	0.027	0.122
Exp_liking_ES_plant	0.030	0.032		**0.057***	0.03	
WTB_NS_pork	0.028	0.032	0.079	−0.017	0.029	0.385
WTB_NS_plant	−0.008	0.028		0.044	0.031	
WTB_ES_pork	0.000	0.029	0.071	−0.038	0.023	0.414
WTB_ES_plant	0.010	0.027		0.040	0.025	

HAM, consumers with a Higher emotional Attachment to Meat for enjoyment; LAM, consumers with a Lower emotional Attachment to Meat for enjoyment.
Exp_liking_NS_"product": expected liking as the dependent variable and interaction between the product and the visual attention paid to the NS as the independent variable;
Exp_liking_ES_"product": expected liking as the dependent variable and interaction between the product and the visual attention paid to the ES as the independent variable;
WTB_NS_"product": willingness to buy as the dependent variable and interaction between the product and the visual attention paid to the NS as the independent variable;
WTB_ES_"product": willingness to buy as the dependent variable and interaction between the product and the visual attention paid to the ES as the independent variable.
** and * denote that the parameters differ from zero at the 5% and 10% significance level, respectively.

Table 4
Subjective understanding of the NS and ES by cluster

	NS		ES	
	HAM	LAM	HAM	LAM
Comprehensibility				
I feel well-informed by the food label	3.5 (1.0)	3.4 (0.9)	3.5 (0.9)	3.5 (1.0)
This label is believable and trustworthy	3.5 (0.9)	3.3 (0.8)	3.6 (0.9)	3.2 (0.9)
This label is easy to interpret	4.3 (0.7)	4.4 (0.7)	4.3 (0.9)	4.3 (0.6)
Help to shop				
This label helps me to understand the product composition	2.7 (1.1)	2.9 (1.2)	2.4 (1.1)	2.5 (1.2)
This label helps me to understand different nutritional (sustainable) values	3.7 (1.1)	3.5 (1.3)	4.1 (0.9)	4.0 (1.0)
This label makes it easier to choose food	3.8 (0.8)	3.8 (1.0)	3.6 (0.9)	3.8 (0.8)
Complexity reduction				
This front-of-pack food label is rather extensive	2.4 (0.9)	2.3 (0.9)	2.4 (1.1)	2.1 (0.8)
Using this front-of-pack food label to choose foods is better than just relying on my own knowledge about what is in them	3.5 (1.2)	3.6 (1.0)	3.7 (1.0)	3.6 (1.0)

HAM, consumers with a Higher emotional Attachment to Meat for enjoyment; LAM, consumers with a Lower emotional Attachment to Meat for enjoyment.
Data expressed as mean values and calculated on a 5-point scale (from 1 = Completely disagree to 5 = Completely agree).
Standard deviations are reported in parentheses.

significant difference was found in the average relative time of fixation for the pork hot dog, either by product or cluster. However, for the plant-based hot dog, LAM consumers paid significantly more attention to the ES than to the NS and when compared to HAM participants (i.e., participants with a higher emotional attachment to meat for enjoyment). This difference in visual attention could elicit a different engagement level for the sustainability aspects of LAM consumers [68,69].

Overall, findings of the mixed models showed that visual attention to the NS and ES was not associated with the expected liking and WTB of participants who had a more positive bond toward meat consumption (HAM consumers). However, interesting trends were identified for this cluster when considering the estimated parameters of the mixed models used to explore the relationship between attention to FOP labels and self-reported expectations and behaviors. Specifically, attention paid to the negative NS of the pork hot dog was linked to a positive direction of the reported expected liking and WTB for the product. Despite this, HAM participants did not show a negative attitude toward either the NS or the ES in terms of label comprehensibility, help to shop, and complexity reduction. These findings are in line with a previous study by Williams et al. [67], who found that the higher the consumer meat attachment level, the less consumers' purchase intention for meat products is influenced by negative eco-labels. Similarly, to our findings, the authors also found no impact of the meat attachment level on label perception. Since previous work showed that consumers with high meat attachment levels have a lower desire to reduce meat consumption [67,70], it is necessary to investigate multistrategy approaches to support meat reduction in this consumer group. For instance, targeted communication campaigns on the use of FOP labels should be developed and tested on different consumer segments before an intervention with such labels. In addition, it is worth noting that previous studies on meat products primarily explored the effects of positive health/sustainability messaging (e.g., "organic feed" or "source of iron") on consumer responses, while the impact of negative claims or labels has received less attention [30,71,72]. Thus, future research on the topic could test the effects that negative labels (e.g., a negative NS or ES) have on consumer purchasing behaviors of meat products (especially of those showing high meat attachment levels) in order to obtain a more robust research body to support both policymakers and manufacturers in their decisions. In addition, future

research could be carried out a similar study involving eye-tracking and positive interpretative FOP labels for PBMAs in association with sensory tasting to explore the potential, combined effect of FOP labels and actual sensory experience to promote PBMAs as meat replacements.

When considering the results from LAM consumers, attention paid to the NS and ES did not affect consumers' purchase intention of either product. Nonetheless, the estimate directions of the mixed models were in line with the hypotheses, thus, with a positive direction for the plant-based hot dog and a negative one for the pork hot dog. However, participants' visual attention did have an impact on the expected liking of both products. Specifically, for LAM consumers, paying more attention to the positive ES of the plant-based hot dog was associated with a higher expected liking for the product. Despite the significance level of this finding showing only weak evidence of this relation—which might be explained by the small sample size not allowing the identification of a stronger significant interaction—this result confirms that labeling highlighting positive sustainable aspects has a positive influence on the sensory perception of food products, as already found in previous research (e.g., [73–76]). This result is also in line with a previous study by Büttner et al. [77], who showed that a positive ES extreme level (e.g., A) can lead to a positive halo effect, with a different impact based on participants' attitudinal characteristics [77]. Furthermore, results for LAM participants also showed that paying more attention to the negative NS of the pork hot dog led to a significantly higher expected liking for the product. This finding follows the estimate direction of HAM participants, showing that, regardless of participants' hedonistic attachment to meat, attention to a negative NS on a meat product could lead consumers to higher sensory expectations. A possible explanation for this result—which is in contrast with H1—could be linked to American consumers' tendency to implicitly associate unhealthy food with tastiness [78]. However, previous research showed that such an association could be based on intercultural differences, such as variations between countries [79]; thus, future studies could investigate whether similar results are confirmed also when focusing on non-American consumers. Despite participants' attention to the negative NS of the meat product having a positive association with sensory expectations, this did not imply an increased purchasing intention for consumers with a lower meat attachment level. As a matter of fact, attention to the label showed a positive estimate direction for HAM consumers only.

When it comes to consumer understanding of the proposed labels, results showed an overall positive evaluation, with no differences between clusters and mean values in line with previous studies [47,48]. However, it should be noted that understanding and knowledge increase with familiarity. Similarly, previous work showed that the higher the familiarity with the label, the higher consumers' public support and engagement level for the label is [80,81]. As a result, we anticipate that communication campaigns on these labeling systems will positively impact the perception of such labels—in terms of comprehensibility, help to shop, and complexity reduction—and provide even more positive results in terms of consumer understanding.

Finally, to the best of our knowledge, this is the first study employing eye tracking in the case of a dual labeling scheme and exploring the effects of visual attention on sensory expectations and purchasing behaviors toward meat and PBMAs. However, this study is not without limitations, which suggest potential opportunities for future research. First, despite the sample size of the study being in line with previous studies employing eye- racking [82–84], it may not allow to detect small differences between groups. In addition, our sample was mainly comprised of female, well-educated consumers, which may limit the generalizability of our results. Thus, future studies with larger, more representative samples are needed to further explore potential consumer differences, including different engagement levels for the sustainability aspect. Second, the same product image was used for both PB and pork hot dogs, with only textual information and FOP labels varying between conditions. Following also a similar approach used in previous works [44,45], this design allowed us to isolate the effect of labeling on consumer expectations and attention, but it may have required participants to make a higher level of abstraction when evaluating the products. Future research could employ product-specific images to increase ecological validity and reduce potential cognitive load associated with abstraction. Third, the products used in this study were hypothetical instead of real products. While this is common practice in consumer studies to eliminate the potential association with the brand's effect [85], future works could investigate whether labels displayed on real products evoke a different level of attention. Fourth, our sample consisted of American consumers, whereas NS and ES are European labels. While this choice allowed us to examine responses from consumers with low prior familiarity with the labels, it may limit the transferability of the findings to European contexts. Future studies could compare responses across countries with different familiarity levels to better understand how prior exposure affects consumer behavior. Finally, this study considers laboratory settings, and it would be of interest to verify whether similar outcomes are met also in real contexts. Additionally, future studies could use a similar approach on consumers who are already familiar with the proposed labels to explore potential differences in consumer behavior based on different familiarity levels.

Conclusions

This research used eye tracking to investigate consumer attention to interpretative nutrition and sustainable labels (the Nutri-Score and Eco-Score) and how this related to their sensory expectation and purchasing intention for pork and plant-based hot dogs. Results showed that while attention to the proposed FOP labels does not impact consumers who strongly associate meat consumption with pleasure and enjoyment (HAM), the sensory expectation of both products was related to visual attention for LAM consumers (i.e., participants with a lower hedonistic attachment to meat). Specifically, a positive and significant direction was identified between the attention paid to the negative NS of the animal product and its expected liking, and between the attention paid to the positive ES of the plant-based product and its expected liking.

Regarding potential implications, our findings confirm the positive effect of favorable sustainable labels on consumers' sensory expectations for PBMAs. Thus, reformulating products to guarantee positive sustainable labels on the front of food packages could encourage consumers' engagement while promoting sustainability in the food sector. In addition, for companies concerned about the potential negative effects that labeling systems such as the NS could have on animal products, our study showed that attention to such a label would not hinder consumers' purchasing intention or expected liking; on the contrary, some consumer segments might link this negative score to a tastier sensory experience. Finally, knowing how much attention consumers pay to specific FOP labels on meat and PBMAs and how this impacts individuals' expectations could assist policymakers when defining tools for tackling meat reduction. Policymakers could also benefit from the results on the subjective understanding as the overall positive findings for both the NS and ES (especially on a population who is not familiar with such labels) may support the decision-making process related to the implementation of labeling schemes needed to guarantee informed food choices.

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.

CRediT authorship contribution statement

Giulia Andreani: Writing – review & editing, Writing – original draft, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Giovanni Sogari:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Methodology, Conceptualization. **Adriano Daniele:** Writing – review & editing, Investigation, Formal analysis, Data curation. **Miguel I Gómez:** Writing – review & editing, Funding acquisition, Conceptualization.

Acknowledgments

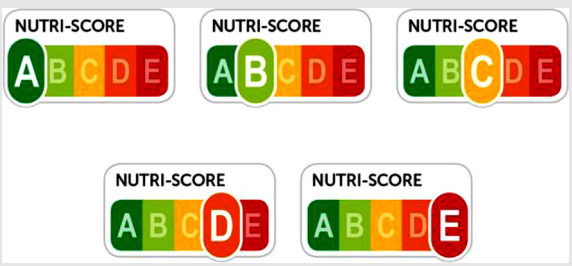
We wish to acknowledge the assistance of Matt Thomas from the Cornell Statistical Consulting Unit during data analysis and the support of Yiran Liu and Katherine Nicolle Palomino during data collection.

Appendix

Table A1
Information provided to participants before starting the experiment

Information 1: Front-of-pack food labels[1]
Front-of-package (FOP) food labels are symbols, schemes, or systems designed to communicate concise and useful information (e.g., nutrition- or environment-related) to consumers to facilitate their food choices. Among the proposed FOP schemes developed, here we described two labels: the NutriScore and the EcoScore.

Information 2: NutriScore[2]
The NutriScore is a five-color nutrition label that displays food products' overall nutritional value. It ranks products from A ("healthiest") to E ("the least healthy") and associates colors ranging from green to red. The calculation is based on an algorithm that takes into account both problematic components, such as fat, saturated fat, salt, sugar, and caloric levels, as well as beneficial elements, such as fiber and protein contents.
An image of the NutriScore is displayed on this page.



Information 3: EcoScore[3]
The EcoScore, similar to the NutriScore, is a food label with five categories, ranging from A (green, the most sustainable option) to E (red, the least sustainable option). While the NutriScore provides an overall assessment of a product's nutritional aspect, this label gives an overall evaluation of a food product's environmental impact to promote more responsible and sustainable consumption. In its algorithm, the EcoScore incorporates various environmental factors, from production to transportation, packaging, country of origin of ingredients, and seasonality of the finished product.
An image of the EcoScore is displayed on this page.

(*continued*)



Information 4: Plant-based alternatives[4]
Plant-based alternatives are food products designed to mimic the animal counterpart in terms of sensory experience and nutritional content by using animal-free ingredients (e.g., soy, pulses, wheat). Examples are plant-based burgers, plant-based hot dogs, plant-based milk, plant-based eggs, and plant-based tuna.

[1]Adapted from:
WHO. (2019). Guiding principles and framework manual for front-of-pack labelling for promoting healthy diet.
De Marchi, E., Cavaliere, A., Pucillo, F., Banterle, A., & Nayga, R. M. (2023). Dynamics of demand-side and supply-side responses to front-of-pack nutrition labels: a narrative review. European Review of Agricultural Economics, 50(2), 201–231. https://doi.org/10.1093/erae/jbac031
[2]Adapted from:
M., D. L., Van Eijsden, M., Van Roost, M. H., De Graaf, K., & Roodenburg, A. J. (2022). The Nutri-Score algorithm: Evaluation of its validation process. Frontiers in Nutrition, 9, 974003. https://doi.org/10.3389/fnut.2022.974003 & Pomeranz, J. L., Wilde, P., Santé Publique France. (2024). Nutri-Score. https://www.santepubliquefrance.fr/en/nutri-score
[3]Adapted from:
Marette, S. (2022). Ecological and/or Nutritional Scores for Food Traffic-Lights: Results of an Online Survey Conducted on Pizza in France. Sustainability, 14(1), 247. https://doi.org/10.3390/su14010247
Colruyt Group. (2024). How do we calculate the Eco-score? https://www.colruytgroup.com/en/conscious-consuming/eco-score/calculate-the-eco-score
[4]Adapted from:
Van Vliet, S., Kronberg, S. L., & Provenza, F. D. (2020). Plant-Based Meats, Human Health, and Climate Change. Frontiers in Sustainable Food Systems, 4, 555088. https://doi.org/10.3389/fsufs.2020.00128
Ketelings, L., Havermans, R. C., Kremers, S. P., & De Boer, A. (2023). How Different Dimensions Shape the Definition of Meat Alternative Products: A Scoping Review of Evidence between 2000 and 2021. Current Developments in Nutrition, 7(7), 101960. https://doi.org/10.1016/j.cdnut.2023.101960
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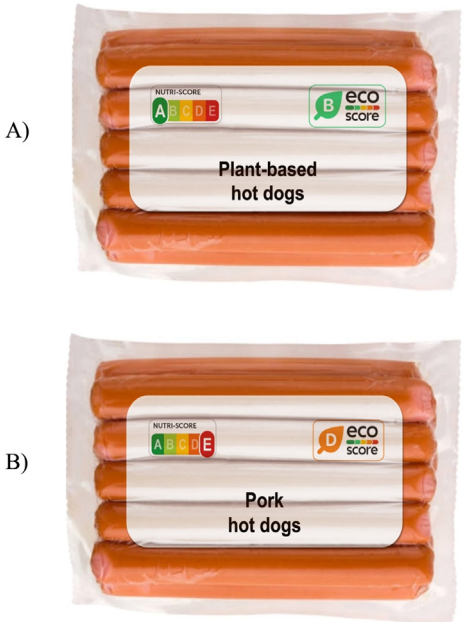


Fig. A1. Images showed to participants during the experiment: (A) plant-based hot dog, and (B) pork hot dog.

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