

RESEARCH ARTICLE

How can carbon labels and climate-friendly default options on restaurant menus contribute to the reduction of greenhouse gas emissions associated with dining?

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Abstract

In this study, we aimed to understand how restaurants can contribute to climate change mitigation via menu design. We investigated two types of interventions: changing the configuration of menu entries with variable side dishes so that the most climate-friendly option is set as the *default* and indicating the greenhouse gas emission of each dish via *carbon labels*. In an online simulation experiment, 265 participants were shown the menus of nine different restaurants and had to choose exactly one dish per menu. In six menus, the main dishes were presented with different default options: the side dish was associated either with the highest or with the lowest greenhouse gas emissions. The other three menus consisted of unitary dishes for which the default rules did not apply. All menus were presented either with or without carbon labels for each dish option. The results indicated that more climate-friendly dish choices resulting in lower greenhouse gas emissions were made with the low-emission than the high-emission default condition, and when carbon labels were present rather than absent. The effects of both interventions interacted, which indicates that the interventions partly overlap with regard to cognitive predecessors of choice behavior, such as attentional focus and social norms. The results suggest that the design of restaurant menus has a considerable effect on the carbon footprint of dining.

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Introduction

In our study, we investigated how restaurant menus can be designed to help guests choose more climate-friendly meals. There are three main reasons for believing that this research direction may be worthwhile. First, humans—especially those living in industrialized societies—need to reduce their greenhouse gas (GHG) emissions substantially to mitigate global warming [1,2]. The impact of agriculture and nutrition on GHG emissions, and their potential to contribute to more sustainable societies, is significant [3,4]. Second, although individual consumption as an isolated factor has only limited influence on GHG emissions at the societal level

[5,6], individuals can significantly reduce their carbon footprint by changing their nutrition behavior. In industrialized countries, nutrition accounts for approximately 15% of an individual's total GHG emissions [5,7], and there are considerable differences between food types in terms of GHG emission levels measured in kilograms of carbon dioxide equivalents per kilogram (kg CO₂e). For example, vegetables such as zucchinis (0.25 kg CO₂e) yield approximately 50 times less GHG emissions than beef (12.29 kg CO₂e; [8]). Third, in industrialized societies, restaurants and similar settings, such as cafeterias and canteens, are often frequented. For example, a large-scale survey in Germany in 2018 revealed that 20% of the participants dined out at least once every week [9]. However, past research on pro-environmental behavior has mainly focused on purchasing food and eating at home [10–12]. At the same time, customers are showing growing interest in restaurants that participate in more ecologically sustainable practices [13].

As a part of ecologically sustainable practices, restaurants can help diners reduce their carbon footprint via dish choices. To this end, changing menu design may result in considerable positive effects. On the one hand, adding information about the ecological impact of the dishes is feasible and both customers and restaurants have expressed an interest in such information [14,15]. *Carbon labels* that provide information about products' GHG emissions have the potential to reduce the carbon footprint of consumer choices [16,17]. Analogously, the field of health promotion has provided meta-analytic evidence that health-related labels move people toward healthier food choices [18]. On the other hand, dishes that feature variable components (e.g., a burger with a beef or vegetable patty) usually have one of these components set as the *default* option. Evidence from several investigations on environmentally friendly behavior suggests that defaults are more likely to be chosen than the other options [12,19,20]. Therefore, the climate impact of chosen dishes with variable components may be significantly reduced by using components with the lowest GHG emissions as the default option.

Both types of intervention can be classified as behaviorally informed strategies, commonly known as “nudges” [10]. *Nudging* [21,22] is defined as a minimal change to the decision-making context with the intention of directing people's behavior toward a desirable outcome for themselves and others without limiting their real or perceived freedom of action. These interventions exclude mandates and bans as well as economic incentives and disincentives. According to a recent review of behaviorally informed interventions aimed at climate-friendly food consumption [10], carbon labels can be classified as *disclosures* when they provide ecological information about a food item (e.g., GHG emissions) and as *warnings* when the label features salient information connoted with emotional value (e.g., traffic-light colors). There are several studies in the context of health- [18,23–25] and environment-related food choice [16,17,23–27] in which the examined labels combined these two types of nudging. In other studies, default and non-default dishes were varied systematically on menus or board menus [28–31]. To the best of our knowledge, no published study has yet examined the combined effects of defaults and carbon labels on food choice, although both types of interventions have yielded promising results in earlier studies and can easily be implemented together. Therefore, the goal of our study was to investigate how the carbon footprint of dish choices can be reduced by using climate-friendly components as default options and by providing information about the GHG emissions for each dish.

Menu defaults

In the past decade, there have been several attempts to reduce the ecological footprint of dish choices in restaurants and similar settings by changing menu design. In a study conducted online that used a hypothetical restaurant setting, participants chose vegetarian meals more

often when they appeared at the top of the menu than in a separate vegetarian section at the bottom [32]. Another online study revealed that approximately three of four participants make vegetarian choices when the menu includes only vegetarian dishes with extra-meat options listed at the bottom of the menu. By contrast, only about half of the participants choose vegetarian dishes when the menu lists vegetarian and meat dishes together [31]. Field studies in campus cafeterias produced similar results: when vegetarian dishes are placed at the top of the board menu, the share of sold vegetarian dishes increases [28,33]. However, none of these studies have directly examined dishes with variable components and it can be argued that a variable component that appears at the most accessible position of the menu (e.g., top or left)—thus constituting the default option—may benefit from similar positive effects.

How are the effects of default-related interventions in restaurant menus related to processes of climate-friendly behavior changes? To begin with, sticking to defaults may result from psychological inertia [34]. Accordingly, people who are indifferent about their dish choices would most likely choose the dish that is most readily available. A similar explanation has to do with the behavioral effort involved in opting against the default [35]. In this case, switching the default component from a beef to a vegetable patty in a burger menu can reduce the carbon footprint of customers who usually order “just a burger,” without having the customers change their actual behavior. Although this view on defaults may sound appealing to practitioners, this may not be the case with restaurant settings: the inertia-based explanation is tailored to situations in which the status quo can be maintained [34], meaning that one does not *have* to make a choice. By contrast, guests at a restaurant are usually forced to choose one of the offered dishes. It is also not very likely that diners are indifferent about what they are going to order.

Alternatively, defaults may be more attention-grabbing or *salient* than other options [28,36]. In menus with a salient dish option (e.g., the one placed at the top, typed in a bigger font, or with a picture of the dish), a customer’s attentional focus is directed to this option more than to the others so that it receives overproportionate weighing in subsequent decision-making [37]. However, this does not necessarily imply that a more salient option is chosen more often. Rather, it depends on which features of the option are made salient, such as price or healthiness. When such features are framed negatively (e.g., when the food item is marked as particularly unhealthy), making them salient can reduce the probability of the option being chosen [38]. We will come back to this topic when addressing carbon labels.

Finally, defaults can be considered implicit recommendations [39,40], thus constituting a kind of social influence. De Vaan et al. [31] found that menu design impacts perceived social norms: a menu with vegetarian defaults suggests that the majority of the guests order a vegetarian dish (*descriptive norm*) and that the majority of the guests would disapprove of ordering a meat dish (*injunctive norm*; [41]). The notion that defaults are implicit recommendations is also consistent with Bacon and Krpan’s finding that an additional explicit recommendation (i.e., declaring the top dish as “the chef’s recommendation”) does not further increase the frequency the dish being chosen [32].

Carbon labels

Labels that indicate food items’ GHG emissions have been examined in dining [23,26,27,42,43] and grocery shopping [16,17,24,25,44] settings. In most cases, such labels combine explicit information (*disclosure*) with a color signal (*warning*; [10]). Results from a field study in a university cafeteria [26] indicate that carbon labels have a rather small effect on the sales of climate-friendly dishes. Specifically, the labels induced a considerable shift from higher- to lower-emission dishes for meat and fish categories, but not for vegetarian categories,

nor was there a significant shift in sales between categories (i.e., the share of sold vegetarian dishes did not increase in total). In laboratory and online studies with fictive dining settings, the findings have been more heterogeneous: Osman and Thornton's [23] results suggest that labels positively affect more climate-friendly dish choices, whereas the results of Babakhani et al. [43] do not. In the context of grocery shopping, the majority of studies have shown that carbon labels [16,17,25,44] have a positive effect, which can explain the consumers' choice behavior beyond a product's price [16,44]. However, a recent online experiment has found that carbon and nutrition labels introduced simultaneously had no effect on the climate impact of food choices [24].

Again, different processes related to consumer behavior changes can be assumed to exist behind carbon labels' impact on food choice. Several studies addressed here [17,23,24,27,42] have emphasized labels' informative content or, more generally, knowledge acquisition as a crucial predictor of climate-friendly food choices. In the literature on environmental behavior changes, three types of knowledge have been identified as relevant [45]: *system knowledge*, which refers to knowledge related to ecosystems and ecological problems (e.g., that human-made GHG emissions cause global warming); *action-related knowledge*, which is related to the behavioral options that people have in order to resolve ecological problems (e.g., reducing meat consumption lowers individual GHG emissions); and *effectiveness knowledge*, which comprises information on the relative benefits or harm of different behavioral options (e.g., replacing a beef patty with a vegetable patty in a burger reduces GHG emissions more than replacing the beef patty with a cheese-spinach patty). Generally, action-related knowledge requires system knowledge, effectiveness knowledge requires action-related knowledge, and all three types of knowledge are necessary for effective pro-environmental behavior.

In line with this reasoning, evidence on carbon labels suggests that such labels only work when customers are familiar with the ecological background of the labels (i.e., have enough system knowledge) and that carbon labels have the potential to encourage climate-friendly dish choices by improving action-related and effectiveness knowledge. Regarding system knowledge, the results obtained by Spaargaren et al. indicate that carbon labels are only effective when embedded in a comprehensive informational strategy [27]. A qualitative study suggests that people need to be informed about the concepts of the carbon footprint and carbon labels [42]. With reference to action-related knowledge, Osman and Thornton [23] have suggested that more accurate information (i.e., labels indicating "CO₂ emissions" and not just "environmental impact") increases the benefits of labels. In line with the idea of effectiveness knowledge, the authors of a shopping study in which the carbon footprint of each product was expressed numerically [17] have argued that such quantified information enables customers to have a realistic idea of food-related GHG emissions, which people tend to underestimate. Carbon labels also improve the accuracy of ranking food items according to their climate impact, even when the labels do not include quantified information and when participants are under time pressure [25].

In food labels, ecological or health information is often combined with a color stimulus, which, in cases of high GHG emissions (or other detrimental effects, such as unhealthiness), should act as a warning signal [10]. To achieve that customers give GHG emissions enough weight when making their dish choices, labels have to be salient [36–38]. In Spaargaren et al.'s field study [27], carbon labels were effective only when they were color-coded; however, an information campaign was introduced at the same time, so it remains unclear to what extent the nascent effect was caused by the colored labels. In this regard, clearer results were obtained in an online coffee-choice experiment [16], whereby the impact of carbon labels was greater when they were designed using traffic-light colors than black-and-white. Two studies have attributed the failure to find an effect of carbon labels on food choice to a lack of salience. De

Bauw et al. [24] argued that carbon labels were not effective in their online grocery setting because the labels appeared below the nutrition labels (which were effective) and were thus less salient. In Babakhani et al.'s eye-tracking experiment [43], participants spent only 2–3 seconds (3% of total dwelling time) on a colored carbon label when studying a page describing a burger dish. The participants also did not look first at the label, which indicates that traffic-light carbon labels are not salient enough so that customers pay special attention to them. However, the lack of salience may have to do with the fact that a picture of the dish was included on each page, which may have been more salient than a rather small label. In sum, there is evidence that salience is an important criterion for the effectiveness of carbon labels, but further research is needed.

Combination of defaults and labels

To our knowledge, the combination of default variations and labels has not yet been studied in the context of dining. However, a similar study [46] combined two types of default in a restaurant setting: one designating an option as “standard,” and one pre-selected option that required diners to deliberately opt out when not choosing the default dish. The results indicated that the effectiveness of the standard default diminished considerably when one option was pre-selected. Other studies have examined the effects of two types of food label. In one case, the effects of organic and animal welfare labels on egg purchases were not additive when combined [47]. Another food shopping experiment [48] demonstrated a similar interaction effect between organic and local origin labeling among European consumers. This less-than-additive effect of two nudging strategies can be accounted for by the basic economic principle of decreasing marginal utility, which suggests that an increasing number of behavioral interventions serving the same goal reduces the effectiveness of each behavioral intervention in relation to that goal [47,48].

From a psychological perspective, there is theoretical [49] and empirical [50] evidence that minimal changes to the configuration of a decision situation (e.g., switching the default), combined with a short information that elicits attentional resources toward certain aspects of the decision in question (e.g., carbon labels), should be an effective measure. The latter type of intervention is often referred to as *prompting* and is common in several fields that have to do with health- or environment-related behavior, such as nutrition [51], recycling [52], and energy saving [53,54]. Prompts are usually placed close to the location where the target behavior happens—for example, a banner at the entry of a supermarket [51] or a sticker on a power strip that reminds users to switch it off before leaving the office [54]. Prompts often include polite persuasive messages so that the recipient's perceived freedom of choice is not reduced [53]. A meta-analysis of experiments that targeted pro-environmental behavior change [50] indicates that prompting and minimal changes to the decisional situation contribute substantially to behavior changes, especially when the two are applied in combination. Therefore, there is also reason to believe that the effects of low-emission defaults and carbon labels add up when applied in combination.

Hypotheses

We investigated whether climate-friendly dish choices in restaurants can be fostered by providing carbon labels for each dish and using the most climate-friendly component as the default option in *modular* dishes with variable components. The study was conducted in imaginary restaurant settings performed online for two practical reasons: on the one hand, the access to real restaurants was restricted (and, temporarily, even prohibited) due to COVID-19 restrictions. On the other hand, online settings allow examining several restaurant types,

including those in which modular dishes are common (e.g., Asian, Burger, and Döner Kebab restaurants) and those that more likely offer *unitary* dishes (e.g., Italian, Greek, and German cuisine). For outcome variables, we focused on both choice behavior and its (hypothetical) climate impact [55] expressed in kg CO₂e.

There is empirical evidence that defaults increase the share of climate-friendly dish choices [28–33] and decrease the GHG impact of dining [33] when a climate-friendly dish is set as the default. From a theoretical perspective, default options are more likely to be chosen because they are more salient than others [28,36] and are associated with perceived social norms [31,40]. Therefore, our first hypothesis was that climate-friendly dish options are chosen more often than others in modular settings in which the option associated with the lowest (vs. highest) GHG emission is set as the default (Hypothesis 1a). Furthermore, we expected that the implied GHG emissions of dish choices should be lower in modular settings in which the option associated with the lowest GHG emission is set as the default, compared to modular settings in which the option associated with the highest GHG emission is set as the default (Hypothesis 1b) and to unitary settings in which this default rule does not apply (Hypothesis 1c).

Some studies have revealed that carbon labels applied to food items initiate more climate-friendly food choices in both grocery shopping and restaurant settings [16,23,27]. Two other studies found a reduction in GHG emissions associated with food choices [17,26]. Two psychological processes can explain the effect of carbon labels: First, when labels convey that food choices affect GHG emissions and specify the quantity of GHG emissions, they enable the acquisition of action-related and effectiveness knowledge, which are crucial predictors of climate-friendly behavior [45]. Second, when labels are made salient (e.g., by using traffic-light colors), diners give GHG emissions more weight when choosing a dish [36–38]. Therefore, we expected that menus with carbon labels would lead to more climate-friendly dish choices (Hypothesis 2a) and to lower GHG emissions associated with these choices (Hypothesis 2b).

Our final goal was to quantify the combined effects of carbon labels and low-emission defaults. We have argued that carbon labels may serve as point-of-decision prompts [51–54] and there is empirical evidence that a combination of minimal situational changes and prompts has more impact on pro-environmental behavior than either one of these interventions alone [50]. At the same time, the two interventions may overlap in terms of the cognitive predecessors of choice behavior. For both the default option and the carbon label, we have argued that, to be effective, they should direct a diner's attention to climate-friendly options [24,28,38]. If the effects of both interventions depend at least partly on their attention-directing function, one can expect that these effects should not be cumulative when both interventions are applied together. As a result, one would then expect a less-than-additive effect of an intervention that combines carbon labels and low-emission defaults. Following this reasoning, we investigated the interaction between defaults and carbon labels in an exploratory manner.

Method

In the main experiment, we provided the participants ($N = 265$) with 9 different menus and asked them to choose one dish from each menu. In a preceding pilot study ($N = 113$), we identified the dishes that were most representative of the restaurant types in question and those that were most popular with guests. The pilot study and developed material are described before reporting the main experiment.

Material construction and piloting

For our experiment, we created menus that were as realistic as possible. This involved selecting dishes that were characteristic of each restaurant type and determining realistic prices as well

as choosing the name of the “restaurant” and the artwork of the menus. Therefore, we conducted an exploratory analysis of real menus that were available online. Then, we browsed the Internet for recipes to identify the ingredients. For each dish, the GHG emissions of the ingredients were determined using Reinhardt’s (2016) Climatarian calculator [8] and added up to the total value stated as CO₂e per portion. In fact, GHG emissions associated with the cooking process were not considered.

We constructed menus for nine different (hypothetical) restaurants. The menus for the Burger, Chinese, Döner Kebab, Indian, Mexican, and Oriental restaurants included three dishes and were *modular*. This means that each dish included a side component with three options that varied in terms of their associated GHG emissions (i.e., low-, medium-, and high-emission options). In total, each modular menu comprised nine options. The three *unitary* menus for the German, Greek, and Italian restaurants each contained six dishes without variable components. These dishes also varied in terms of their GHG emissions.

The sample of the pilot study consisted of 113 participants (mean age = 27.38 years, *SD* = 9.84) who filled out an online questionnaire. They were given a list of 13–14 dishes for every unitary menu (i.e. German, Greek, and Italian), 7–10 main dishes for every modular menu (i.e., Burger, Chinese, Döner Kebab, Indian, Mexican, and Oriental), and four side dishes (i.e., candidates for variable components) for every main dish in the modular menus. For each unitary menu, the participants indicated on a five-point Likert scale how familiar they were with each dish in the respective restaurant type, with an additional response option indicating that they did not know the dish at all. For the modular menus, the participants were asked which main dish they would order in the respective restaurant. To respond to this question, they selected up to four main dishes and ranked them as first, second, third, and fourth choice. Additionally, the participants were asked which of the four side dishes (usually one beef, one poultry, one cheese, and one plant-based option) would fit best for every main dish. These questions had a multiple-choice format with the additional options “none of them” and “don’t know the main dish.”

For the unitary menus, we chose two dishes with the highest familiarity ratings (between 1 and 5, with “unknown” rated as 0) for each GHG emission category. For each modular menu, three main dishes were chosen that had the highest popularity rank, were the most frequently ranked, or were the least frequently indicated as unknown. The decision for which of these criteria was given priority was not fixed but varied depending on pragmatical reasons (e.g., the variety of selected dishes). For the side dishes, we selected between two options for one category (in most cases, cheese vs. poultry for the medium-emission category). The option that was more often indicated as appropriate to the respective main dish was chosen for the final menu. [S1–S15](#) Tables present the results of the pilot study in more detail.

Main experiment

Participants. The online experiment took place between July 31st and August 15th 2020. The participants were acquired through social media platforms (Facebook, Instagram) and from the authors’ circle of acquaintances, which means that the majority of participants are German residents. In the course of acquisition, we told participants that the experiment related to dish preferences in restaurants, but we did not inform them about the ecological background of our study. During the data collection period, Germany was moderately affected by the COVID-19 pandemic, and restaurants were open under certain conditions; particularly, guests were required to leave their contact data upon ordering and to wear a mask except when sitting at the table.

Restaurant Type	Low-emission ("green") category		Medium-emission ("yellow") category		High-emission ("red") category	
	Range (kg CO ₂ e)	Label design	Range (kg CO ₂ e)	Label design	Range (kg CO ₂ e)	Label design
Burger	0.21 – 0.29		0.64 – 1.03		2.38 – 2.46	
Chinese	0.45 – 0.64		0.83 – 1.02		2.04 – 2.23	
Döner Kebab	0.29 – 0.35		0.79 – 1.12		1.94 – 2.00	
Indian	0.56 – 1.09		1.02 – 1.47		2.23 – 2.68	
Mexican	0.97 – 1.38		1.43 – 1.84		2.64 – 3.05	
Oriental	0.33 – 0.38		0.77 – 1.16		1.98 – 2.11	
German	0.48 – 0.51		1.26 – 1.49		2.23 – 2.97	
Greek	0.57 – 0.80		1.37 – 1.40		1.87 – 1.90	
Italian	0.13 – 0.23		0.86 – 0.95		1.29 – 1.85	

Fig 1. Range of greenhouse gas emissions within categories and design of carbon labels for every restaurant. kg CO₂e = kilograms of carbon dioxide equivalents per dish.

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The initial link to the questionnaire was clicked by 605 persons, of which 283 (47%) completed the questionnaire. Of those, 11 were excluded because they misinterpreted the carbon labels as health labels or indicators of tanginess unrelated to ecological sustainability. As most of the dishes with the lowest GHG emissions were exclusively plant-based, we expected that the intervention would have no effect among vegans. Therefore, we excluded five other persons who indicated following a vegan diet. Finally, two persons were excluded because they indicated being younger than 18 years, although they had initially declared to be of legal age. The final sample thus consisted of 265 participants, of which 215 (81%) were female. The participants' age ranged between 18 and 75 years (mean = 35.78, *SD* = 12.89).

Material. For each of the nine menus, we created two versions: one with carbon labels for every dish option and one without. An individual carbon label was created for each menu (Fig 1). All labels shared two central properties: a number with two decimal places that indicated the GHG emissions in kg CO₂e per portion and a colored signal that was red for high-emission (1.29–3.05 kg CO₂e), yellow for medium-emission (0.64–1.84 kg CO₂e), and green for low-emission (0.13–1.38 kg CO₂e) dishes. In the six modular menus (i.e., Burger, Chinese, Döner Kebab, Indian, Mexican, and Oriental restaurants), every dish had a “red,” a “yellow,” and a “green” option, depending on which variable component had been chosen. For example, the Chinese menu included a coconut curry that could be ordered with beef (“red”), chicken (“yellow”), or tofu (“green”). The three unitary (i.e., German, Greek, and Italian restaurants) menus each included two “red” (e.g., beef roast with onions), two “yellow” (e.g., gyros with tzatziki), and two “green” (e.g., spaghetti aglio e olio) dishes. Regarding the associated GHG emissions, the label categories did not overlap within one menu, with one exception that affects the Indian menu (see Fig 1).

In the modular menus, the default component was included in the description of the main dish, whereas the other two components were placed below, following the pattern of “alternatively with (e.g.) falafel instead of (e.g.) beef.” In the high-emission default condition, the “red” option was set as the default, and the “green” option was placed at the lowest position. The low-emission default condition followed the opposite order, with the “yellow” option always being the first of the two non-default options. Fig 2 depicts an example. In the unitary menus,



Fig 2. Modular dish (Oriental menu) with (a) and without (b) carbon labels. The upper image represents the high-emission default, the lower image represents the low-emission default.

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one of the “yellow” dishes was always placed on top, and the two “green” dishes appeared at the bottom (Fig 3).

The dish prices were determined in accordance with typical restaurant prices in Germany and were presented in euros. Vegetarian dishes are usually lower in price than meat dishes; therefore, the prices used in this experiment were positively associated with GHG emissions, especially in the unitary menus. In the modular menus, the same pricing was used for all component options for one dish so that the carbon impacts of the choices were at least partly independent of their monetary consequences. The “red” dishes usually had beef or veal components, the “yellow” ones included pork, lamb, poultry, or cheese, and the “green” dishes



Fig 3. Unitary (Italian) menu with (a) and without (b) carbon labels.

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were always vegetarian and, in most cases, exclusively plant-based (vegan). Although labels indicating vegetarian or vegan dishes are commonplace, they were not included in the study menus because their effects on dish choices are considerable [32], meaning they could confound our expectations for the carbon labels. We also did not include fish or seafood dishes in this study. S1–S30 Figs show all the original (German) menus, and S31–S39 Figs show the English translations of the labeled versions with high-emission defaults.

Design and procedure. The experiment followed a two-factor mixed design. The factor *Default* varied between the modular menus with high-emission defaults (HE), the modular menus with low-emission defaults (LE), and the unitary menus (UM) for which defaults did not apply. Default was administered within participants and partly within items because an HE and an LE version existed for every modular menu, whereas the unitary menus pertained exclusively to the UM condition. The factor *Labeling* varied between a condition that included carbon labels and one that did not. Labeling was administered between participants and within items (i.e., there were versions with and without labels for every menu).

The participants were randomly assigned to the label or the no-label condition and completed all nine menu items (restaurant types) which were presented in random order. Every modular menu appeared randomly as an HE or an LE item. The participants “ordered” exactly one dish per menu by clicking on an arbitrary position in the dish description. The ordering function was locked for 30 seconds to ensure that the participants actually read the menus before choosing a dish. Prior to the menu, a photograph showing the typical atmosphere of the corresponding restaurant type was presented, accompanied by the sentence “Welcome to (e.g.) the Greek restaurant Ilios.” By adding this stimulus, we sought to create a choice environment that was as close as possible to the real dish-ordering situation, also bearing in mind that restaurants that offer take away or delivery dishes online also often have photographs of their interiors on their homepages. However, no picture of any dish was shown. After the experiment, the participants were asked for demographic data and information on their usual eating behavior, including the frequency of restaurant visits and the frequency of meat consumption in general and particularly in restaurants (see Table 1). The participants in the carbon label condition were then asked about the meaning of the labels to ensure that they had

Table 1. Demographic data and self-reported eating behavior.

				Mean	Standard deviation
Age				35.78	12.89
Gender	49 male	215 female	1 diverse		
Diet ^a	245 omnivore	20 vegetarian			
How often do you have meat? ^b				3.47	1.37
How often do you have meat in a restaurant? ^c				2.22	1.30
How often do you dine out? ^c				2.86	1.12

N = 265.

^a Five participants who indicated following a vegan diet were excluded.

^b 0 = less than monthly or never, 1 = once per month, 2 = more than once per month, but less than weekly, 3 = once per week, 4 = more than once per week, but not daily, 5 = once per day, 6 = more than once per day.

^c 0 = rarely or never, 1 = 5 to 10 times per year, 2 = once per month, 3 = 2–3 times per month, 4 = once per week, 5 = more than once per week, 6 = daily.

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understood them. As above, we excluded 11 participants who misinterpreted the labels as unrelated to environmental issues.

The whole study was administered online via SoSciSurvey [56] and took between 10 and 15 minutes. The participants were instructed to complete the study on a tablet or a laptop computer and were asked not to use a smartphone. Before starting the online questionnaire, the participants were informed of the scope of the study and their data processing rights. They could participate only after declaring being at least 18 years old and providing informed consent. At the end of the questionnaire, the participants received a full debriefing of the aims and the structure of the experiment. Ethical approval was not requested because the data were gathered anonymously and negative consequences for participants were not expected.

Results

The data associated with our experiment is included in the supplemental material: [S1 File](#) contains the data at the participant level, [S2 File](#) contains the data at the response level, and [S3 File](#) contains a legend for both data files. Given that dish choices and their associated GHG emissions depended strongly on both the participants and the items (menus), we performed our main analyses on the response-level data. We considered linear-mixed model (LMM) analyses to be the best way of dealing with the metric GHG emission data because such analyses allow for the computation of fixed and random effects at both the participant and item levels [57,58]. For the categorical dish choice data, multinomial logit models [59] were analyzed using a hierarchical procedure, starting with participants and restaurants as random factors. [S4 File](#) contains the R code of the whole analysis and [S5 File](#) includes the results of all analyses, except for descriptive statistics for the dependent variables by experimental group, which have been calculated via Excel. A sensitivity power analysis performed using GPower (version 3.1.9.2; [60]) with $\alpha = .05$ (two-tailed) and the obtained sample size of 265 revealed that a group difference of $\delta = 0.4$ would be detected with 90% power. For GHG emissions, this would correspond to a reduction of 0.31 kg CO₂e per meal based on the obtained standard deviation of 0.772.

Preliminary analyses

Before conducting the main analysis, we examined whether the frequency of choosing high-, medium-, and low-emission dishes, and the mean GHG emission per dish were associated with gender, age, and self-reported eating and dining behaviors. For the analyses regarding gender, we excluded one non-binary participant and conducted Welch two-sample t-tests to

Table 2. Pearson correlations for dish choices, associated greenhouse gas emissions, and self-reported eating behavior.

	1.	2.	3.	4.	5.	6.	7.	8.
1. High-emission dish choices	1	-.36***	-.69***	.95***	.14*	.54***	.39***	.03
2. Medium-emission dish choices		1	-.42***	-.11	-.08	.15*	.19**	.09
3. Low-emission dish choices			1	-.84***	-.07	-.64***	-.52***	-.10
4. Mean greenhouse gas emission per dish				1	.12	.60***	.46***	.07
5. Age					1	.08	.07	-.08
6. Frequency of having meat						1	.60***	.08
7. Frequency of having meat in a restaurant							1	.66***
8. Frequency of dining out								1

N = 265

**p* < .05

***p* < .01

****p* < .001.

<https://doi.org/10.1371/journal.pclm.0000028.t002>

compare male and female participants. The results showed that male participants chose high-emission dishes more often than female participants, $t(76.24) = 5.171$, $p < .001$, whereas the opposite pattern was observed for low-emission dishes, $t(91.86) = -4.428$, $p < .001$. Medium-emission dish choices were not associated with gender, $t(81.96) = -1.384$, $p = .17$. The associated GHG emission per dish was significantly higher among male than female participants, $t(77.01) = 5.546$, $p < .001$. Therefore, we included gender as a covariate in the main analyses.

Table 2 shows Pearson correlations for the frequency of high-emission and low-emission dish choices, GHG emissions per dish, age, the frequency of dining out, the frequency of having meat, and the frequency of having meat when dining out. Importantly, and not surprisingly, both the frequency of having meat and the frequency of having meat when dining out were substantially correlated with dish choices and the associated GHG emissions. As these two items were also highly interrelated ($r = .60$) and the frequency of eating meat in general showed higher correlations with dish choice and GHG emissions than the frequency of eating meat in restaurants, we included the frequency of eating meat in general as a further covariate.

Dish choice

The proportion of low-, medium-, and high-emission dish choices as a function of default variation and labeling is shown in Table 3 and Fig 4. To analyze these data, we computed multinomial logit models running R (version 4.1.0; [61]) and the mlogit package (version 1.1.1; [59,62]) on response-level data. We selected the medium-emission dish choice as the reference level because a recent study indicated that consumers are more likely to substitute high-emission meat products (e.g., beef) with medium-emission meat alternatives (e.g., chicken) than with low-emission meat-free alternatives [63]; this suggests that it may be insufficient to focus only on low-emission dishes. Following a hierarchical procedure, we started with a baseline model that only included participants and items (restaurants) as predictors. This model was significant, $\chi^2(6) = 20.05$, $p < .001$, McFadden $R^2 = .004$, with restaurant type predicting the proportion of low-emission dish choices ($p < .001$).

Next, we added labeling (with vs. without carbon labels) and two predictors referring to default variation (HE vs. other, LE vs. other) to the analysis (Model 1). The predictive power significantly exceeded that of the baseline model, $\chi^2(6) = 264.87$, $p < .001$, McFadden $R^2 = .055$. HE defaults increase the proportion of high-emission dish choices by 7.0% ($p < .001$), but does not significantly reduce the proportion of low-emission dish choices. LE defaults

Table 3. Relative frequency of high-, medium-, and low-emission dish choices and greenhouse gas (GHG) emissions as a function of default variation and labeling.

	Labeling	Default variation		
		High emission	Low emission	Unitary menu
Share of high-emission dish choices				
	Without carbon labels	.590	.210	.459
	With carbon labels	.356	.174	.336
Share of medium-emission dish choices				
	Without carbon labels	.294	.338	.352
	With carbon labels	.341	.308	.430
Share of low-emission dish choices				
	Without carbon labels	.116	.453	.189
	With carbon labels	.303	.518	.234
Mean (and SD) of GHG emissions per dish in kg of CO ₂ equivalents				
	Without carbon labels	1.766 (0.768)	1.103 (0.741)	1.439 (0.704)
	With carbon labels	1.384 (0.787)	1.035 (0.727)	1.291 (0.683)

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reduce the proportion of high-emission dish choices (-22.4%) and increase the proportion of low-emission dish choices (26.7%, both $p < .001$). This largely supports Hypothesis 1a. In line with Hypothesis 2a, carbon labels reduce the proportion of high-emission dish choices by an estimated 7.0% ($p < .001$) and increase that of low-emission dish choices by 5.5% ($p = .007$).

For Model 2, we added interaction terms between default variation and labeling. The predictive power increased further, $\chi^2(4) = 19.60$, $p < .001$, McFadden $R^2 = .059$. Accordingly, carbon labels significantly reduce the proportion of high-emission dish choices ($p = .001$) but do not increase the proportion of low-emission dish choices. The effects of default variation on dish choice proportions were not affected by this model extension. However, labeling interacted with default variation (HE vs. other) in terms of low-emission dish choices ($p = .006$). The estimated proportion of low-emission dish choices increases by 9.7% in the HE default condition, compared to a mere 2.3% in the LE default condition, and 3.4% in the UM condition.

Finally, Model 3 also included gender (male vs. other) and meat-eating frequency. Once more, the predictive power increased significantly, $\chi^2(4) = 455.40$, $p < .001$, McFadden $R^2 = .123$. As one might expect, the self-reported frequency of meat consumption predicts high-emission dish choices positively and low-emission dish choices negatively (both $p < .001$). Male gender is associated positively with high-emission choices ($p < .001$) but not with low-emission dish choices. The effects reported in the previous model remain stable. Table 4 summarizes Models 2 and 3.

Greenhouse gas emissions

Using R, we ran LMM analyses for the GHG emissions (total mean = 1.33 kg CO₂e) on the response-level data. We used the packages lme4 (version 1.1.27.1; [64]) for model construction, lmerTest (version 3.1.3; [65]) for significance testing, and MuMIn (version 1.43.17; [66]) to calculate explained variances (R^2) at the model level. For the iterative procedures, we used a restricted maximum likelihood method with generalized least square estimates, as recommended by the literature [57,58,64]. For all significant effects, we reported the unstandardized estimates (regression weights, b) as effect size measures. Degrees of freedom were estimated using Satterthwaite's method [65].

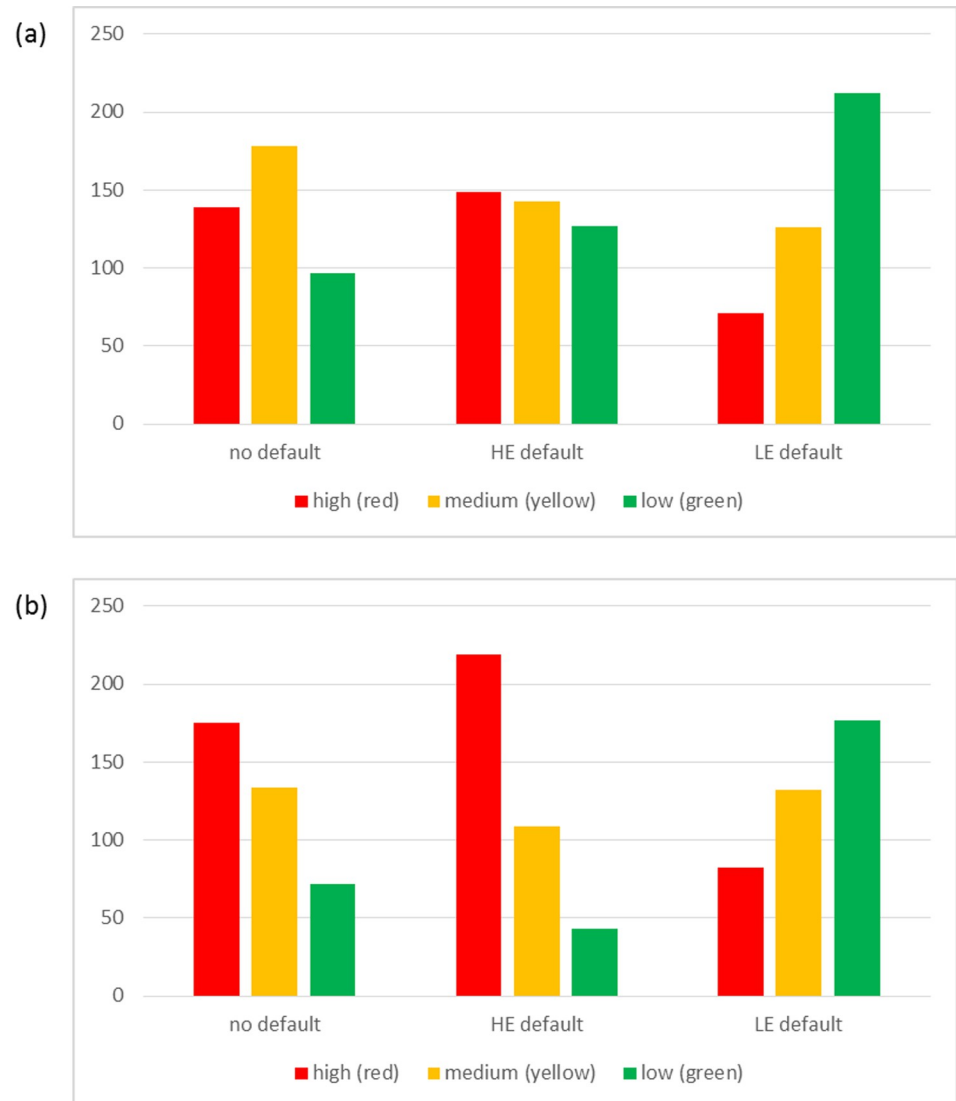


Fig 4. Number of high-, medium-, and low-emission dish choices in the presence (a) and absence (b) of carbon labels. HE = high emission, LE = low emission.

<https://doi.org/10.1371/journal.pclm.0000028.g004>

For the default conditions, we computed two contrasts; one comparing LE with HE and one comparing LE with UM. In the first step of the LMM analysis, these two default contrasts, one labeling contrast (with vs. without carbon labels), and their interactions were included as fixed effects. Random effects (intercepts) were included at both the person and item levels. The explained variance (R^2) was .10 for fixed effects only and .43 for fixed and random effects combined. Table 3 and Fig 5 show the mean GHG emissions of the chosen dishes as a function of experimental conditions. The contrast of the HE versus LE conditions was again significant, $t(7.524) = -3.009$, $p = .018$, $b = -0.251$. In line with Hypothesis 1b, GHG emissions were higher in the HE default condition than in the LE default condition. The contrast between LE and UM was not significant, which means that Hypothesis 1c was not supported. Labeling was also a significant predictor, $t(262.65) = 4.519$, $p < .001$, $b = -0.100$. In line with Hypothesis 2b, the presence of carbon labels was associated with lower GHG emissions. The interaction between the HE versus LE contrast and labeling was significant, $t(2211.08) = 5.845$, $p < .001$, $b = 0.105$.

Table 4. Results of the multinomial logit model analyses (last two models) on high- and low-emission dish choices, compared with medium-emission dish choices.

	Dish Choice	Model 2			Model 3		
		<i>b</i>	<i>SE</i>	<i>p</i>	<i>b</i>	<i>SE</i>	<i>p</i>
Intercept	high	0.090	0.148	.542	-1.303	0.249	< .001
	low	-0.794	0.163	< .001	0.631	0.215	.003
Participant	high	-0.000	< 0.001	.524	-0.000	< 0.001	.941
	low	0.000	< 0.001	.123	0.000	< 0.001	.526
Restaurant type	high	-0.005	0.024	.827	-0.005	0.024	.823
	low	0.004	0.024	.873	0.004	0.025	.864
Labeling	high	-0.258	0.081	.001	-0.242	0.082	.003
	low	0.009	0.097	.926	-0.149	0.101	.140
Default 1: LE vs. other	high	0.376	0.136	.006	0.396	0.138	.004
	low	0.077	0.162	.633	0.080	0.167	.634
Default 2: HE vs. other	high	-0.520	0.149	< .001	-0.630	0.151	< .001
	low	1.013	0.144	< .001	1.163	0.151	< .001
Labeling* Default 1	high	-0.071	0.116	.537	-0.106	0.118	.368
	low	0.400	0.145	.006	0.469	0.150	.002
Labeling* Default 2	high	0.208	0.130	.110	0.185	0.132	.162
	low	0.106	0.126	.400	0.154	0.130	.238
Gender: Male vs. other	high				0.507	0.128	< .001
	low				-0.257	0.157	.101
Meat-eating frequency	high				0.329	0.051	< .001
	low				-0.417	0.041	< .001

HE = high emission, LE = low emission.

<https://doi.org/10.1371/journal.pclm.0000028.t004>

The effects of default variation and labeling were again less than additive: when the menu contained carbon labels, setting a low-emission dish as the default had a weaker effect on GHG emissions associated with dish choice than when no labels were included.

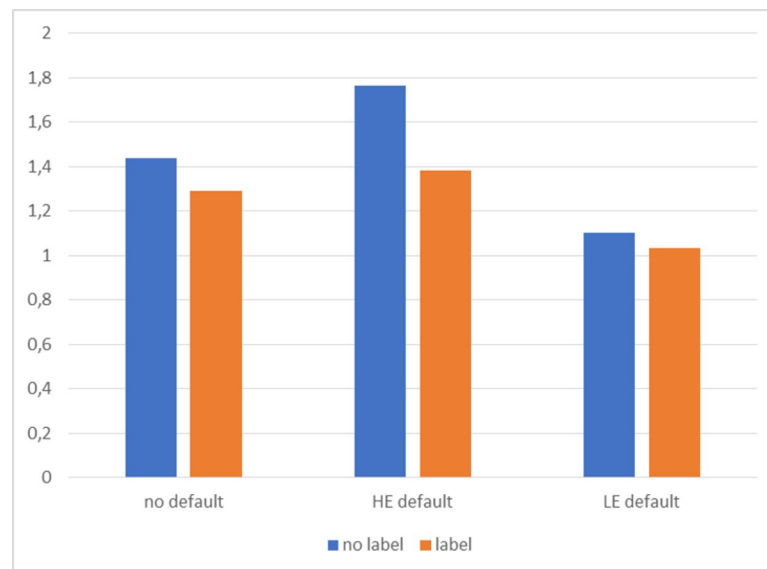


Fig 5. Mean emission per chosen dish in kilograms of carbon dioxide equivalents. HE = high emission, LE = low emission.

<https://doi.org/10.1371/journal.pclm.0000028.g005>

Table 5. Results of the linear-mixed model (LMM) analyses on greenhouse gas emissions (kg of CO₂ equivalents) associated with dish choice.

	LMM without covariates			LMM with covariates		
	<i>b</i>	<i>SE</i>	<i>p</i>	<i>b</i>	<i>SE</i>	<i>p</i>
Intercept	1.337	0.117	< .001	0.926	0.157	< .001
Labeling	-0.100	0.022	< .001	-0.057	0.022	.011
Default 1: LE vs. UM	-0.029	0.164	.866	0.138	0.189	.479
Default 2: LE vs. HE	-0.251	0.083	.018	-0.232	0.126	.072
Labeling*Default 1	-0.026	0.017	.137	-0.014	0.022	.545
Labeling*Default 2	0.105	0.018	< .001	0.120	0.024	< .001
Meat-eating frequency				0.143	0.013	< .001
Gender: male vs. female				-0.126	0.096	.189
Labeling*Gender				-0.016	0.023	.475
Default 1*Gender				-0.164	0.096	.089
Default 2*Gender				-0.026	0.097	.854
Labeling*Default 1*Gender				-0.018	0.022	.436
Labeling*Default 2*Gender				-0.021	0.024	.375

HE = high emission, LE = low emission, UM = unitary menu.

<https://doi.org/10.1371/journal.pclm.0000028.t005>

In the second step, we introduced gender contrasts, with one contrast comparing the responses of male and female participants and one comparing the responses of male and non-binary participants. (As there was only one non-binary participant, we did not interpret the results on the basis of this second contrast.) In addition, the frequency of meat consumption was included as a metric covariate. These two variables and the interactions of gender with the experimental factors (including three-time interactions) were added to the model's fixed effects. R^2 was .18 for fixed effects only and .43 for fixed and random effects combined. A chi-squared difference analysis revealed that the extended model added significant explanatory power, $\chi^2(10) = 143.91, p < .001$. The self-reported frequency of meat consumption was a highly relevant predictor of GHG emissions per chosen dish, $t(258.8) = 10.851, p < .001, b = 0.143$. Gender was not significant and there was no interaction between gender and either intervention type. Interestingly, the main effect of labeling remained significant, $t(260.9) = -2.563, p = .011, b = -0.057$, whereas the main effect of HE versus LE defaults was not, $t(38.93) = -1.848, p = .072, b = -0.232$. The interaction between labeling and HE versus LE defaults remained significant when the covariates were included, $t(2255) = 5.103, p < .001, b = 0.120$. Table 5 summarizes the results of the LMM analyses.

Discussion

With this online experiment, we sought to investigate the influence of carbon labels on dish choices and the associated GHG emissions in restaurant settings. We further examined whether varying the default between high-emission (HE; “red”) and low-emission (LE; “green”) options in modular menus makes a difference and investigated how default variation and labeling interact. Finally, we considered the interplay of these two interventions with self-reported meat-eating behavior.

Defaults and labels

In the six modular menus, the share of high-emission dish choices decreased significantly when the low- instead of the high-emission option was set as the default. This result was accompanied by a significant average reduction of 0.5 kg CO₂e (31.7%) per dish for the LE

condition compared to the HE condition and thus confirmed our assumption that using climate-friendly dishes as default options fosters climate-friendly dining. Compared to the three unitary menus in which defaults were not varied, an average reduction of 0.3 kg CO₂e (21.6%) per dish was reached in the LE condition. However, this result was not statistically significant and may also be of limited practical relevance because changing unitary menus to modular ones would take more effort for restaurant owners than switching the default options in existing modular menus. In sum, the present results confirm earlier evidence that default variation influences choice behavior in restaurant and canteen settings [28–32]. In a long-term field study administered at a Swedish university canteen [33], diners reduced the GHG emissions of their food choices by around 4.5% when a vegetarian dish instead of a meat dish was presented at the top of the board menu. The present study replicated and exceeded this finding using a different menu design (modular table menus) and a different method (online survey), which suggests that changes in diners' choice behaviors induced by climate-friendly defaults result in reduced GHG emissions.

Likewise, carbon labels appear to have an effect on both choice behavior and the associated GHG emissions. As hypothesized, there was a decrease in high- and an increase in low-emission dish choices when colored labels, together with a number indicating the GHG emission in kg CO₂e, were included for each dish. On average, the GHG emission per dish was 0.2 kg CO₂e (13.5%) lower when carbon labels were present than when they were absent. This effect was smaller than that evoked by varying defaults, but reached statistical significance. The present results thus support earlier studies whereby an effect of carbon labels on both behavioral [23,26] and impact outcomes [26,27] was found in restaurant or canteen settings. In more general, the results confirm the notion that behavioral interventions classified as *information* and *warning* [10] apply to restaurant settings. Notably, as the present study did not vary systematically between information-only labels (i.e., black and white) and warning-only labels (i.e., colored without numerical information), we were unable to determine which of these components had a stronger impact. However, in line with Spaargaren et al.'s [27] findings, we argue that both the information and warning aspects of labels are necessary for substantial changes in dish choice behavior and its associated GHG emissions. Regarding the underlying cognitive processes, this implies that effectiveness knowledge is needed so that diners can identify the difference that they can make when choosing a more climate-friendly dish [45]. This may motivate them to consider climate friendliness when choosing their dishes. In addition, such effectiveness-related information should be salient [37] so that the diners' attention is focused on climate-related information that they might otherwise not have considered when ordering at a restaurant, even when they have a positive view on climate protection in general. According to the integrated model proposed by Klöckner and Matthies [49], both attentional and motivational processes are relevant for ecological decision-making.

It appears that the two types of behavior change investigated here—choosing more low-emission dishes and fewer high-emission dishes—are not equally affected by defaults and carbon labels. While “green” defaults foster both types of behavior change, “red” defaults act against the reduction of high-emission dish choices, but seemingly do not affect low-emission dish choices. Likewise, carbon labels lead to a reduction of high-, but not to an increase of low-emission dish choices. This is in line with recent findings on grocery shopping [63] indicating that “nudged” consumers substitute carbon-intensive meat products with less intensive ones (e.g., chicken) rather than with plant-based alternatives. Moreover, carbon labels increase low-emission dish choices significantly by 0.38 kg CO₂e (21.6%) on menus with “red” defaults but not on menus with “green” defaults (0.07 kg CO₂e; 6.2%) or unitary menus (0.15 kg CO₂e; 10.3%). This aligns with the principle of decreasing marginal utility from basic economic

theory, which holds that the beneficial effect of each measure declines with every additional measure included in the intervention [46–48].

From a psychological perspective, we suspect that the less-than-additive effect of low-emission defaults and carbon labels reflects an overlap between both interventions with regard to processes of behavior change. First, both defaults and labels guide a diner's attention toward making an environmentally friendly decision, the consequence being that together, the interventions are mutually diminishing. According to the integrated decision-making model [49], either of these interventions alone can therefore serve as a situational cue that activates the attentional stage of environment-related decisions. The other interventions would then have only limited power to promote this decision-making process further. Moreover, we believe that defaults and labels overlap in terms of social norms, especially injunctive ones [41]. As argued by McKenzie et al. [40], defaults work as recommendations, and there is evidence that this function is also shared by default-like settings in menus [31,32]. Regarding GHG labels, it can be assumed that especially their warning function reflects an injunctive norm: dishes with a red label can be considered as being socially disapproved of. We have argued in the previous paragraph that to a certain extent, ordering a dish can be classified into ecological decision-making, which is a variant of planned behavior [49]. In the theory of planned behavior [67], injunctive norms—usually referred to as “subjective norms”—are one of the key predictors of planned behavior.

The findings on dish choices and GHG emissions converge largely, with one exception: When gender and self-reported meat-eating behavior were added as covariates, default variation remained a significant predictor of dish choice but not of GHG emissions. In terms of GHG emissions, the effect of default variation overlaps with existing behavioral tendencies, while the effect of labeling remains stable. We argue that among the participants provided with carbon labels, there may be a shift toward dishes with lower GHG emissions within one category. For example, participants in the carbon label condition who often eat meat may be more likely than those in the unlabeled condition to choose the red dish with the lowest carbon impact (as compared to other red dishes) or one of the poultry or pork dishes from the “yellow” category [63]. However, as we did not expect this result pattern, this explanation is somewhat speculative. It appears that the success of menu defaults and carbon labels depends substantially on existing meat-eating tendencies. Future research in this area should more systematically address the moderating role of existing eating habits.

Limitations and further directions

A substantial drawback of the present study may be that, rather than examining actual dining behavior, we have only investigated hypothetical dish choices in an online setting. This has two implications for the validity of our results. First, it is questionable whether the results can be generalized from our online setting to real dining situations, which means that we cannot make a decisive conclusion about how the combination of defaults and labels would work in a real restaurant setting. At the same time, artificial settings, such as ours, are more controllable in terms of the effects to be investigated because several confounding variables can be excluded. Confounding variables may include, for example, social influences in a group of diners or the presence of other diners, including the sight and smell of what they have ordered. Moreover, individual preferences for or reluctances toward certain dishes carry no weight in an experimental design that involves nine different “restaurants” and 30 different menus. Such a design is barely feasible in a field study.

Second, and more specifically, the fact that the participants' choice behaviors had no actual consequences for them (i.e., they neither ate nor paid for the dishes they had ordered) involves

a relatively high risk of unauthentic response tendencies in terms of social desirability [68] or consistency [69]. This possibility may be especially relevant to the carbon label condition because the labels made the ecological intention of this study more transparent. We assume that social desirability is an expression of injunctive social norms; in this sense, it is possible that the normative influence of labels is more pronounced in online than in field settings. The person-response consistency bias may explain why the effect of labels on dish choice and related GHG emissions overlaps strongly with self-reported meat-eating behavior: participants with a pro-environmental self-concept are more likely to report a low-meat diet after being confronted with the huge climate impact of meat dishes, as conveyed by the carbon labels. At the same time, participants with a less pro-environmental self-concept may have shown reactance toward the labels and consistently reported a meat-intensive diet.

The menus used in our experiment were shorter than those in real restaurants, which may also limit the generalizability of our results. However, we made a decision to limit the number of options because too many options can lead to suboptimal choices, including random choices [70], yielding meaningless data. We believe participants would be especially prone to such random choices in online settings like this one, where they do not really eat what they have chosen. This was among our main reasons for piloting the menus to maximize the diversity and popularity of the dishes offered.

In light of the potential drawbacks associated with online settings, it is worth noting that the results of our experiment match those of several field studies on the influence of both LE defaults [28–30,33] and carbon labels [26,27]. In other words, different methodological approaches suggest that both interventions contribute substantially to a reduction of the GHG impact of dining. Future research should apply a combination of defaults and labels in real restaurant settings to improve the generalizability of our combined results.

Another clear limitation of our study relates to quantitative and qualitative aspects of sampling. While the sample size fell within the usual range of online psychological studies, it was relatively small for a behavioral economics study. The minimum effect size for 90% statistical power exceeds clearly what might be expected for carbon labeling, especially when benchmarked against field studies (e.g., [27]). Additionally, as younger participants and women are overrepresented, the generalizability of our results is limited. Gender was associated with dish choice behavior and its carbon impact; that is, more women than men chose “green” dishes causing lower GHG emissions. This pattern of results was as expected (e.g., [71]), and we suggest that the experiment should be replicated with a larger and more balanced sample, especially regarding gender.

It is also worth considering that the variation of defaults may reflect a mere order effect, in which the option at the top of the menu is more likely to be chosen than those below. This claim aligns with how earlier restaurant studies [28,32] implemented defaults by varying the order of dishes on the menus. Beyond that, the present study not only varies the order but also highlights the default option graphically and spatially separates descriptions of alternative side dishes and their associated main dishes (Fig 2). The question of whether this form of default variation is more effective than mere order variation remains to be addressed empirically. To do so, the order of dishes within unitary menus might be varied to compare the effect size with that of a default variation in modular menus.

Focusing on choice behavior and its implied climate impact can be seen as a strength of the present study. However, a critical point is that the GHG information used for both the labels and the impact-oriented measurement relies on a single source [8]. As pointed out there, the CO₂ equivalents reflect expectable average values for the whole production and delivery chains of groceries in Germany. This implies that special conditions, such as regional and organic farming, were not considered and that the GHG values used in this study are not generalizable

to other countries. Nevertheless, it can be expected that the size differences between GHG emissions of plant-based (vegan) dishes, dishes that include dairy or poultry products, and dishes that involve ruminant meat are only minorly affected by such details. In terms of environmental communication, providing diners with rough information regarding the scale of GHG emissions associated with what they are going to order should already contribute to changes in choice behavior. From the perspective of impact measurement, a substantial reduction in GHG emissions should be detectable when diners order, for example, chicken instead of beef or a vegan instead of a dairy-based dish, regardless of the details concerning the farming, manufacturing, and transportation of the groceries involved.

It is also of practical relevance that traffic-light symbols are an effective way of indicating products that are good or bad for the environment [16,23,25,27] but that these colors are also commonly used to convey health-related information, such as the *nutri-score*, which has been introduced officially in several European countries [72]. In two studies in which both nutrition and environmental labels were included [15,24], only the nutrition labels had a significant effect on food choice. Given that people should consider health- and environment-related information when deciding what to eat, an optimal design for a combined health-and-ecological label remains to be created and evaluated.

The main result of this investigation is that default settings and labels with disclosure and graphical warning functions, both of which are classified as nudging interventions [10,22,36], have considerable effects on guests' ecologically relevant decisions in restaurants. Operators who want to reduce their restaurant's carbon impact may implement carbon labels or, if the menu has a modular design, introduce the least carbon-intensive version of a dish as the default version. However, with regard to psychological accounts of behavior changes, it would be advantageous to have more precise insights into the psychological concepts involved in these decisions. Although we have discussed concepts such as attention (saliency), different types of knowledge, and different types of social norms in detail, the obtained results do not allow us to make decisive conclusions. Such conclusions would be of particular interest when considering individual differences. Depending on whether participants are ready to adapt their dining habits to contribute to mitigating the climate crisis and, if so, how far that behavioral adaptation has evolved [73], different psychological processes will be relevant to different individuals; consequently, different types of behavioral interventions may be needed. Therefore, we want to encourage further psychological research on "eco-nudging" to take a deeper look into these processes from an individual differences perspective.

Supporting information

S1 Fig. Original (German) menu of the Burger restaurant with high-emission defaults and carbon labels.

(TIFF)

S2 Fig. Original (German) menu of the Burger restaurant with high-emission defaults and without carbon labels.

(TIFF)

S3 Fig. Original (German) menu of the Burger restaurant with low-emission defaults and carbon labels.

(TIFF)

S4 Fig. Original (German) menu of the Burger restaurant with low-emission defaults and without carbon labels.

(TIFF)

S5 Fig. Original (German) menu of the Chinese restaurant with high-emission defaults and carbon labels.

(TIFF)

S6 Fig. Original (German) menu of the Chinese restaurant with high-emission defaults and without carbon labels.

(TIFF)

S7 Fig. Original (German) menu of the Chinese restaurant with low-emission defaults and carbon labels.

(TIFF)

S8 Fig. Original (German) menu of the Chinese restaurant with low-emission defaults and without carbon labels.

(TIFF)

S9 Fig. Original (German) menu of the Döner Kebab restaurant with high-emission defaults and carbon labels.

(TIFF)

S10 Fig. Original (German) menu of the Döner Kebab restaurant with high-emission defaults and without carbon labels.

(TIFF)

S11 Fig. Original (German) menu of the Döner Kebab restaurant with low-emission defaults and carbon labels.

(TIFF)

S12 Fig. Original (German) menu of the Döner Kebab restaurant with low-emission defaults and without carbon labels.

(TIFF)

S13 Fig. Original (German) menu of the Indian restaurant with high-emission defaults and carbon labels.

(TIFF)

S14 Fig. Original (German) menu of the Indian restaurant with high-emission defaults and without carbon labels.

(TIFF)

S15 Fig. Original (German) menu of the Indian restaurant with low-emission defaults and carbon labels.

(TIFF)

S16 Fig. Original (German) menu of the Indian restaurant with low-emission defaults and without carbon labels.

(TIFF)

S17 Fig. Original (German) menu of the Mexican restaurant with high-emission defaults and carbon labels.

(TIFF)

S18 Fig. Original (German) menu of the Mexican restaurant with high-emission defaults and without carbon labels.

(TIFF)

S19 Fig. Original (German) menu of the Mexican restaurant with low-emission defaults and carbon labels.

(TIFF)

S20 Fig. Original (German) menu of the Mexican restaurant with low-emission defaults and without carbon labels.

(TIFF)

S21 Fig. Original (German) menu of the Oriental restaurant with high-emission defaults and carbon labels.

(TIFF)

S22 Fig. Original (German) menu of the Oriental restaurant with high-emission defaults and without carbon labels.

(TIFF)

S23 Fig. Original (German) menu of the Oriental restaurant with low-emission defaults and carbon labels.

(TIFF)

S24 Fig. Original (German) menu of the Oriental restaurant with low-emission defaults and without carbon labels.

(TIFF)

S25 Fig. Original (German) menu of the German restaurant with carbon labels.

(TIFF)

S26 Fig. Original (German) menu of the German restaurant without carbon labels.

(TIFF)

S27 Fig. Original (German) menu of the Greek restaurant with carbon labels.

(TIFF)

S28 Fig. Original (German) menu of the Greek restaurant without carbon labels.

(TIFF)

S29 Fig. Original (German) menu of the Italian restaurant with carbon labels.

(TIFF)

S30 Fig. Original (German) menu of the Italian restaurant without carbon labels.

(TIFF)

S31 Fig. English translation of the Burger restaurant menu with high-emission defaults and carbon labels.

(TIFF)

S32 Fig. English translation of the Chinese restaurant menu with high-emission defaults and carbon labels.

(TIFF)

S33 Fig. English translation of the Döner Kebab restaurant menu with high-emission defaults and carbon labels.

(TIFF)

S34 Fig. English translation of the Indian restaurant menu with high-emission defaults and carbon labels.

(TIFF)

S35 Fig. English translation of the Mexican restaurant menu with high-emission defaults and carbon labels.

(TIFF)

S36 Fig. English translation of the Oriental restaurant menu with high-emission defaults and carbon labels.

(TIFF)

S37 Fig. English translation of the German restaurant menu with carbon labels.

(TIFF)

S38 Fig. English translation of the Greek restaurant menu with carbon labels.

(TIFF)

S39 Fig. English translation of the Italian restaurant menu with carbon labels.

(TIFF)

S1 Table. Pilot study values of main dishes for the Burger restaurant menu. M = mean of popularity rank. SD = standard deviation of popularity rank. n without rank = number of participants who did not rank the dish. n unknown = number of participants who did not know the dish. Selected dishes = dishes selected for the final study.

(DOCX)

S2 Table. Pilot study values of main dishes for the Chinese restaurant menu. M = mean of popularity rank. SD = standard deviation of popularity rank. n without rank = number of participants who did not rank the dish. n unknown = number of participants who did not know the dish. Selected dishes = dishes selected for the final study.

(DOCX)

S3 Table. Pilot study values of main dishes for the Döner Kebab restaurant menu. M = mean of popularity rank. SD = standard deviation of popularity rank. n without rank = number of participants who did not rank the dish. n unknown = number of participants who did not know the dish. Selected dishes = dishes selected for the final study.

(DOCX)

S4 Table. Pilot study values of main dishes for the Indian restaurant menu. M = mean of popularity rank. SD = standard deviation of popularity rank. n without rank = number of participants who did not rank the dish. n unknown = number of participants who did not know the dish. Selected dishes = dishes selected for the final study.

(DOCX)

S5 Table. Pilot study values of main dishes for the Mexican restaurant menu. M = mean of popularity rank. SD = standard deviation of popularity rank. n without rank = number of participants who did not rank the dish. n unknown = number of participants who did not know the dish. Selected dishes = dishes selected for the final study.

(DOCX)

S6 Table. Pilot study values of main dishes for the Oriental restaurant menu. M = mean of popularity rank. SD = standard deviation of popularity rank. n without rank = number of participants who did not rank the dish. n unknown = number of participants who did not know

the dish. Selected dishes = dishes selected for the final study.
(DOCX)

S7 Table. Pilot study values of side dishes for the Burger restaurant menu. n = number of participants who found the side dish appropriate. Selected side dishes = side dishes selected for the final menus.

(DOCX)

S8 Table. Pilot study values of side dishes for the Chinese restaurant menu. n = number of participants who found the side dish appropriate. Selected side dishes = side dishes selected for the final menus.

(DOCX)

S9 Table. Pilot study values of side dishes for the Döner Kebab restaurant menu. n = number of participants who found the side dish appropriate. Selected side dishes = side dishes selected for the final menus.

(DOCX)

S10 Table. Pilot study values of side dishes for the Indian restaurant menu. n = number of participants who found the side dish appropriate. Selected side dishes = side dishes selected for the final menus.

(DOCX)

S11 Table. Pilot study values of side dishes for the Mexican restaurant menu. n = number of participants who found the side dish appropriate. Selected side dishes = side dishes selected for the final menus.

(DOCX)

S12 Table. Pilot study values of side dishes for the Oriental restaurant menu. n = number of participants who found the side dish appropriate. Selected side dishes = side dishes selected for the final menus.

(DOCX)

S13 Table. Pilot study values of unitary dishes for the German restaurant menu. M = mean of the familiarity scale. SD = standard deviation of the familiarity scale. n unknown = number of participants who did not know the dish. Selected dishes = dishes selected for the final study.

(DOCX)

S14 Table. Pilot study values of unitary dishes for the Greek restaurant menu. M = mean of the familiarity scale. SD = standard deviation of the familiarity scale. n unknown = number of participants who did not know the dish. Selected dishes = dishes selected for the final study.

(DOCX)

S15 Table. Pilot study values of unitary dishes for the Italian restaurant menu. M = mean of the familiarity scale. SD = standard deviation of the familiarity scale. n unknown = number of participants who did not know the dish. Selected dishes = dishes selected for the final study.

(DOCX)

S1 File. Participant-level data of the experiment.

(CSV)

S2 File. Response-level data of the experiment.

(CSV)

S3 File. Legend for the data files.

(CSV)

S4 File. R codes of preliminary and main analyses.

(TXT)

S5 File. R outputs of preliminary and main analyses.

(TXT)

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