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Eco-friendly labeling biases judgments of environmental impact☆,☆☆,☆☆☆

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ABSTRACT

Recent research has identified some psychological barriers that contribute to human inaction on climate change. In the current study, we explore how people perceive the environmental impact of eco-labelled products. We developed a new computerized footprint illusion task based on the trial-by-trial causal learning task. Participants were presented with monthly records of a community household carbon footprint. Thus, this task differs from previous ones in that it allows learning from data. Participants tended to judge the environmental impact of new buildings to be weaker when they were labelled as “green” than when they were no labelled, indicating an effect of eco-labelling. This biased perception occurred even when participants were exposed to information that should assist them in making accurate and unbiased judgments, which indicates that the expectations induced by the labels affected how participants interpreted the data. Implications for the design of strategies aimed at promoting better understanding of the environmental impact of human choices and at minimizing environmental harm are discussed.

1. Eco-friendly labeling biases judgments of environmental impact

Climate change represents one of the greatest challenges for humankind, both scientifically and societally. The fight against climate change has often been framed in terms of individual actions (e.g., consumer habits). However, this perspective is not always successful, partly because people tend to be reluctant to change their behavior.

Previous research has identified some psychological barriers that hinder behavioral change and contribute to human inaction on climate change (Gifford, 2011). Interestingly, this research has also identified and described cognitive biases that underlie or contribute to these barriers. Thus, for example, an optimistic bias can contribute to the underestimation of environmental risks, which in turn may hinder engagement in sustainable actions and policies (Gifford, 2011; Hatfield & Job, 2001); in a similar vein, confirmation bias (selectively seeking information that aligns with prior beliefs or understimating information that contradicts them) may explain why people remain skeptical about anthropogenic climate besides the evidence (Zhao & Luo, 2021).

Some of these biases are specifically related to how people perceive the environmental impact of their actions. For example, the pseudoinefficacy bias refers to the underestimation of the contribution of individual actions (Västfjäll et al., 2015) and it may reduce engagement into pro-environmental behaviours by considering that only actions at a large scale can contribute for a meaningful impact (Zhao & Luo, 2021).

Some studies have shown that eco-friendly labelling (e.g., “ecological”, “green”, or “organic”) can induce biased judgments and decisions. Thus, for example, Schuldt and Schwarz (2010) found that the label "organic" can influence perceptions of calorie content. Specifically, the authors found that organic-labelled cookies were considered lower in calories and more appropriate for frequent consumption than conventional cookies (see Durand et al., 2025 for a recent meta-analysis of this

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organic halo effect on calories estimation). The effect of eco-labelled products on human judgment seems so pervasive that previous research has shown that the position of environmentally friendly labelled products on a simulated shopping list can influence the perceived environmental friendliness of the entire list, even affecting subsequent purchase decisions (Sörqvist, Heidenreich, et al., 2024; see Sörqvist et al., 2024b for similar results).

In the current study, we will also focus on the biases that are induced by eco-friendly labelling, because (as we will argue), they can potentially encourage unsustainable behavior. One example of these biases is the *Negative footprint illusion* (Gorissen & Weijters, 2016; Holmgren, Andersson, & Sörqvist, 2018; Holmgren, Kabanshi, et al., 2018; Kim & Schuldt, 2018; Kusch & Fiebelkorn, 2019; Sörqvist & Langeborg, 2019; Uzlu Dolanbay & Yıldıran, 2025). Gorissen and Weijters (2016) first described this illusion in the context of food consumer behavior. The authors found that the environmental impact of one meal (i.e., its carbon footprint) was perceived as smaller when the meal contained an additional eco-friendly side dish than when it did not. For example, a burger accompanied by a sustainable side (e.g., an organic apple) was perceived to have a lower environmental impact than a burger without the organic side dish (Gorissen & Weijters, 2016; Experiment 2). However, this perception is clearly erroneous, given that eco-friendly products still contribute with a carbon footprint (albeit smaller than their regular counterparts), and in no case they can compensate for, or reduce, the environmental impact of the whole, combined meal (i.e., there is no such thing as a food item with a "negative" footprint).

The Negative footprint illusion has been reported in several contexts and with different products such as environmentally certified vs. conventional buildings (Holmgren, Andersson, & Sörqvist, 2018; Holmgren, Kabanshi, et al., 2018), or hybrid vs. petrol cars (Kim & Schuldt, 2018), suggesting that our perception about the environmental impact of our actions can be easily biased by green labels. The behavioral consequences of this illusion can be relevant. For example, the idea that green products may compensate for the impact of conventional ones may induce people to increase their consumption, in an attempt to reduce the environmental effect of other behaviors, thus producing just the opposite outcome (Hope et al., 2017; Kaklamanou et al., 2015; Seebauer, 2018).

1.1. Green labels. From biased expectations to biased information processing

The Negative footprint illusion has been traditionally assessed by comparing the estimated environmental impact of a product or action A, against that of a combination of products or actions A + B (B being labelled as eco-friendly). This green labelling biases people's judgments, causing an underestimation of the impact of A + B when compared to A alone, so that $(A + B) \leq A$. Thus, the Negative footprint illusion reflects a bias in the expectations about the environmental effects of A + B relative to those of A.

In real-life situations, these expectations are usually confronted with experience or actual data that could in turn be used to adjust the expectations. For example, a city government can decide to restrict traffic as a measure to improve the air quality in the city, but once the measure is implemented, inhabitants can compare their initial expectations regarding the effectiveness of the measure to actual data on air quality. In fact, we propose that the evaluation of human actions is subject to a process of causal learning, by which people use the data at hand to judge the effects of actions and measures on the environment. Thus, even when our expectations are biased, exposure to information may act as a debiasing experience that can protect us from some of the negative outcomes of the negative footprint illusion and related biases, through a learning process. In fact, many governmental campaigns already leverage this possibility, by providing citizens with data and information about the state of the climate, aiming at promoting individual action and reducing change in climate caused by human actions (anthropogenic climate change). Nevertheless, this strategy could have limited success.

One reason for this limited success is that the green labeling not only affects our expectations, but also changes how we interpret our experience and the data we are presented with, so that the information can eventually be unable to correctly adjust the expectations. This has been shown, for example, in research using food choices. Sörqvist et al. (2015) asked participants to rate how good they thought some banana slices tasted. Participants reported that eco-friendly labelled fruits tasted better than conventional ones, even if they were actually assessing the same product. This result, known as the green-halo effect, was interpreted as evidence for a distorted flavor evaluation originated by label-induced expectations. That is, the expectations about the eco-friendly product were apparently able to guide perception and decision making, overriding actual experience and affecting the reports of the perceived taste (see Litt & Shiv, 2012).

Similarly, it could be possible that expectations about sustainability also bias how we encode and interpret information about the impact that our actions have on the environment and on climate change. If this were true, then confronting experience with actual data would not be an effective strategy to clarify the human causal role on climate change, because the labels could bias peoples' interpretation of the provided evidence. In fact, consistent with this rationale, a growing body of evidence suggests that causal inferences, in general, can be influenced by pre-existing beliefs and expectations (White, 1995, 2003), to the point that these pre-existing beliefs have been proposed as a potential mechanism underlying biased causal inferences.

For example, Blanco et al. (2018) conducted a study in which participants were asked to examine the potential relationship between a fictitious government taking actions (potential cause) and the improvement in some city indicators (potential effect). The authors presented the same information in two fictitious scenarios which differed only in the political orientation of the agent that carried out the actions (either a left-wing party or a right-wing party). Although the information provided to participants contained no statistical connection between the government's actions and the changes in the indicators, participants selectively developed a biased perception of causality when the causal relationship aligned with their expectations (i.e., their political self-positioning). Thus, these results suggest that causal inferences can be biased in the service of previously acquired causal expectations that are meaningful for the participant's belief system (see also Blanco et al., 2020a). A similar result was also reported by Vicente et al. (2023) when comparing the causal judgments of believers and nonbelievers in pseudoscience after observing identical data from fictitious patients using either alternative or scientific medicine. If, as previously stated, we assume that people use their causal judgment to decide whether they take actions on environmental contexts, then these decisions are also subject to the same biases we observe in causal learning experiments.

Thus, consequent with the research on causal learning, it seems plausible that expectations induced by eco-friendly labelled products (i.e., a green halo effect, or more generally an eco-labelling effect) contribute to a biased perception of the environmental data about the impact of such products, maintaining the negative footprint illusion even when the actual evidence does not support this belief. On the other hand, it is possible that participants use the evidence at hand to correct their erroneous expectations induced by the labels. Since previous research on the negative footprint illusion did not provide participants with actual evidence about the impact of the actions or products, this possibility was, as far as we know, never examined in this literature. Thus, the aim of the current experiment is to test the effect of eco-friendly labels and, in particular, whether the eco-label effect may contribute to mantain the negative footprint illusion in a task in which participants have access to relevant information that may help them reduce or even eliminate the bias. We will explore whether the eco-labelling contributes to biased judgment through a distorted perception of the information provided. Specifically, we expect eco-labeling to influence judgments of environmental impact, with eco-labelled items perceived as having a lower impact than identical non-labelled products. Additionally, we will investigate whether a footprint illusion arises when actual carbon footprint data are presented. If so, we expect the recalled carbon footprint of eco-labelled elements to be underestimated.

2. Method

2.1. Ethics statement

The Ethical Review Board of the University of Deusto reviewed and approved the methods reported in this article, and the study was conducted according to the approved guidelines.

2.2. General overview of the experiment

Following the scenario designed by Holmgren, Andersson, and Sörqvist (2018), participants had to judge to what extent the household carbon footprint of a fictitious community was affected by the construction of new houses (either labelled as eco-friendly or not). However, and differing from previous research, we presented information about the household carbon footprint for the two time periods: before and after the new houses were built. This procedural modification will allow for testing whether the footprint illusion still appears when information about the environmental impact of consumer actions is provided. Note that under these procedure, participants' responses about the environmental impact can be viewed as a form of causal learning, where individuals learn the causal relationship between community features (the new houses present or absent) and the environmental outcomes (e.g., household carbon footprint estimations).

We developed a new computerized footprint illusion task, based on the trial-by-trial causal learning task with a continuous outcome (Chow et al., 2019) and trials with and without the target cause were presented in two consecutive phases (Blanco et al., 2020b).

2.3. Participants

A sample of 199 adults (106 women, 92 men, and one trans woman) aged between 18 and 82 years old (M_{age} = 35.34, SD = 12.43) were recruited via Prolific Academic (Palan & Schitter, 2018), and were compensated for their participation with £0.50 (£5/hour). The participation was offered only to those applicants in Prolific Academic's pool with English as their first language (to ensure that the instructions were correctly understood) and who had not taken part in previous studies carried out by our research team. Participants were randomly assigned to the experimental conditions resulting in 106 participants in the experimental group (new houses labelled as eco-friendly) and 93 in the control group (no reference made to the environmental properties of new houses). The sample size was decided for economic/practical reasons (we recruited the maximum sample that was posible). A subsequent sensitivity analysis (Perugini et al., 2018) conducted in G*Power (Erdfelder et al., 1996) revealed that this this sample size allows to detect an effect of $d = 0.40$ or larger for a between-subject contrast with 80 % power (note that, by Cohen's standards, $d = 0{,}50$ is considered a medium-sized effect).

As an indication, a quick literature search in published articles shows some variability in the effect sizes reported for the green halo/eco-labelling effects (e.g., d = 0.62 in Sörqvist et al., 2013; d = 1.0 in Sörqvist et al., 2015, Experiment 3), while a recent meta-analysis (Durand et al., 2025) suggests that the overall effect is large (d = 0.87, albeit this analysis focuses on the effect on perceived calorie count). Concerning the negative footprint illusion, we can also find either small (e.g., $d = 0.20$, Gorissen & Weijters, 2016, Experiment 2) or large (e.g., d = 0.85, Holmgren, Andersson, & Sörqvist, 2018, Experiment 1) effects. As argued above, our sample size is large enough to capture medium-sized effects 80 % of the time. However, when interpreting this information about observed effect sizes in published research, one has to bear in mind the large heterogeneity in methods, measures, and designs that these studies use. For example, while some studies report differences in taste, others measure estimated carbon footprint, calorie counts, or willingness to pay. This heterogeneity, together with potential publication biases (Durand et al., 2025), moves to caution when interpreting the effect size estimations obtained from single studies, and only as a complement to the sensitivity analyses conducted above (Albers & Lakens, 2018).

2.4. Design and procedure

Throughout the first phase (Phase A, i.e., before the new houses were built), all participants were presented with 12 monthly records of the community household carbon footprint (thus they learnt about the environmental impact of regular houses alone, A). In the second phase (Phase A + B), participants were informed that the community had grown by incorporating new houses. Thus, 12 additional carbon footprint records were presented, showing the combined emmisions produced by both the regular houses (A) and the new houses (B). See the details in Fig. 1.

The participants were ramdomly assigned to either one of two groups (experimental or control). The only difference between them was the way in which the new houses were described in the second phase: in the experimental group, the instructions of the second phase presented the new houses (B) in the A + B phase as "environmentally certified" and "eco-friendly". By contrast, in the control group, this information was not mentioned (full instructions are available in Appendix A). Then, the two groups were trained with the same information (see Fig. 1).

After training, a test phase was presented and participants were required to estimate the environmental impact of the new houses, as well as the monthly household carbon footprint before and after their construction.

Finally, to control for individual differences in environmental concern, we included two questionnaires after footprint illusion task: the Climate Change Beliefs questionnaire developed by Jessani and Harris (2018), and the GREEN Scale (Haws et al., 2014). See Table 1 for a summary of the experimental design.

In line with the literature described in the Introduction, participants in the experimental group are expected to experience an eco-labelling effect, that is, they are expected to judge the environmental impact of the new houses as weaker than participants in the control group. Additionally, asking participants to provide estimations of the monthly household carbon footprint before and after the new construction will allow us to assess group differences in the integration of the partial information provided about the household carbon footprint during the training session. Thus, if participants in the experimental group developed a negative carbon footprint illusion, then we would observe that they report a positive (rather than negative) environmental impact of adding new green houses to the community (i.e., they would judge the impact of A + B to be smaller than that of A alone). This should contrast with participants in the control group, who should report a negative impact of building new houses (i.e., A + B > A).

2.5. Footprint illusion task

Before starting Phase A, all participants were told they would observe a sequence of 12 trials showing the monthly measures of the environmental impact that the 100 houses in one community produce together as a whole (i.e., combined household carbon footprint). The measures would range from 0 (very low impact) to 100 (very high impact).

After reading the instructions, participants were exposed to a series of 12 trials that comprise the twelve monthly measures of Phase A (see Fig. 1). Each trial started with an inter-trial interval (ITI) screen depicting the community houses on a cloudy day, and three animated dots in the center of the screen to indicate that the information was

	Carbon footprint values												Average (SD)	Median	Kurtosis	Asymmetry
Phase A	51	53	55	58	59	60	62	63	64	67	69	71	61 (6.34)	61	-0.98	0
Phase A+B	57	59	61	64	65	66	68	69	70	73	75	77	67 (6.34)	67	-0.98	0

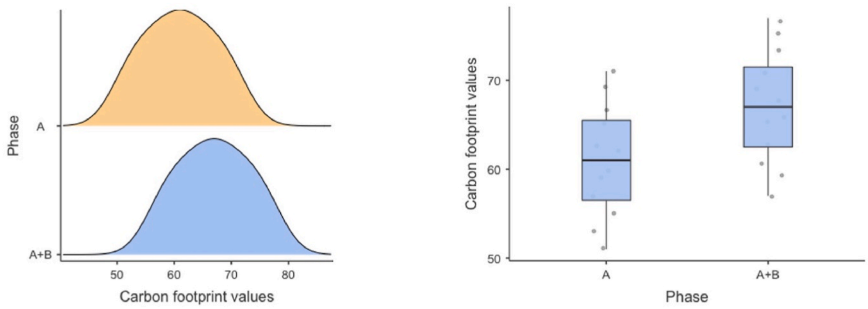

Fig. 1. Carbon footprint values presented on each of the 12 trials of each phase of the study, and descriptive statistics of the carbon footprint shown in the training session.
Upper panel presents the carbon footprint values used in Phase A (regular houses alone) and Phase A + B (regular houses + new houses). The values in Phase A + B were created by adding six points to the values presented in Phase A. This strategy allows to emulate the impact of the new houses in the averaged emissions of greenhouse gases from Phase A to Phase A + B, while keeping the rest of the training features (i.e., kurtosis, standard deviation) unchanged between the two phases. The twelve specific carbon footprint values were presented in random order for each participant within each phase. The bottom panel depicts densities (left panel) and box plots (right panel) of the carbon footprint values on each phase (data on boxplots are jittered to avoid overlapping).

Table 1
Summary of the experimental design.

Group	**Training**			**Test**	**Questionnaires**
	A	New houses description	A+B		
Experimental	12 trials before the new houses were built	Eco-friendly	12 trials after the new houses were built	Judgments	GREEN Scale Climate Change Beliefs Questionnaire
Control		No information			

about to be displayed (see Fig. 2). One second later, the monthly household carbon footprint estimation was presented, followed by a button with the words "Show the next estimation" written on it. This button appeared 1.5 s after the monthly household carbon footprint estimation was presented to ensure that participants have, at least, one and a half seconds to process the information. Once participants clicked on the button, a new ITI screen was presented. There was no time-limit for progressing through the task (participants advanced at their own pace).

After 12 trials in which the monthly measures of the impact of the

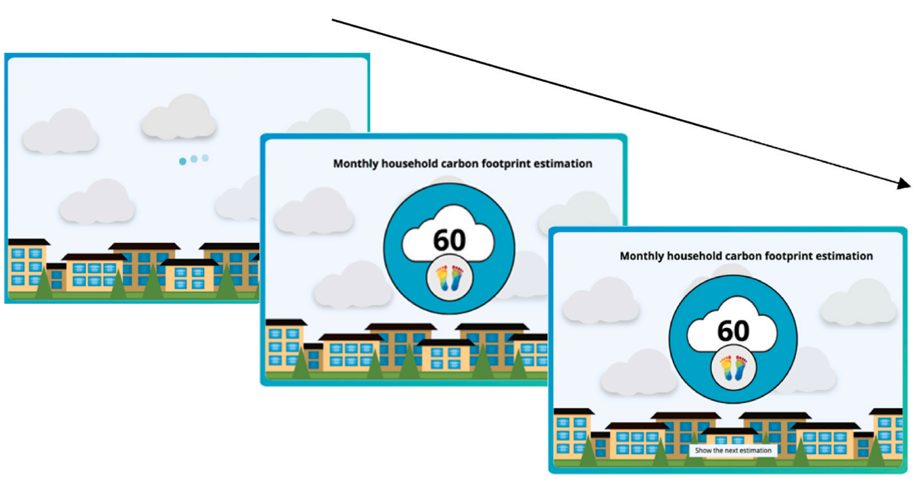

Fig. 2. Schematic procedure of a trial in the Footprint illusion task. This figure is composed of three screenshots from the original task.

whole community of 100 houses were presented, the A + B Phase started. Both groups received new instructions informing that the community had decided to build 30 additional houses and that they will be presented with a new series of measures of the combined household carbon footprint of the whole community once the additional houses had been built. Thus, the estimations would refer now to a larger set of houses (A + B) than in the previous phase (A).

In the experimental Group, the instructions stated that all the new houses that were added in this phase were environmentally certified and eco-friendly. These instructions were accompanied by a picture of a house with solar panels on the roof, and an "ECO" label to ensure that participants did not miss this information. The instructions for the control group were exactly the same, but details about the environmental certification of the houses were omitted. In line with this instructional manipulation, the pictures of the new houses in the control group did not feature solar panels, labels, or any other element indicating that they were special at all. In sum, both groups were now exposed to a phase in which 30 new houses had been added to the 100 that were already in the city, but the experimental and control groups differed in the labeling and description of these new houses (i.e., "ecological" vs. no information).

Then, twelve additional trials were presented following the same procedure detailed for Phase A. To ensure that participants did not miss that the number of houses was larger in this phase than in the previous one (i.e., 130 instead of 100), additional pictures of houses were added to the background image on each trial. To make it consistent with the instructions, these new houses were drawn with solar panels on the roof in the experimental group, and without the solar panels in the control group (see Fig. 3).

The test phase started immediately after the last training trial of the Phase A + B was completed, and it comprised three questions: one impact rating and two footprint estimations. First, all participants were asked to rate how the new houses affected the household carbon footprint of the community by using an interactive visual scale (impact rating). The scale ranged from −100 (the new houses clearly decreased the household carbon footprint) to +100 (the new houses clearly increased the household carbon footprint). In addition to these two extreme values, there were three additional values labelled: −50 (the new houses slightly decreased the household carbon footprint), 0 (the new houses did not affect the household carbon footprint) and +50 (the new houses slightly increased the household carbon footprint). To ensure that participants understood the meaning of the scale, we used five text descriptions and colored emojis representing the meaning of each marked value. Thus, when participants moved the on-screen mouse pointer above one of the five marked values of the scale, help boxes popped up presenting a description of that value (see Fig. 4, Panel A). Impact ratings can be considered as analogous to causal judments in the causal learning literature, as they are basically assessing a causal belief (i.e., the extent to which the introduction of new houses had a causal impact on the carbon footprint) and are collected in a similar way as in causal learning experiments.

After giving the impact rating, participants were required to provide a value that represented the monthly household carbon footprint before the new houses were added (phase A) and after they were added (phase A + B) (see Fig. 4, Panels B and C respectively). They gave their answers by using a scale labelled at the extremes (0 and 100).

Finally, participants completed the GREEN Scale (Haws et al., 2014) and the Climate Change Beliefs questionnaire (CCB, Jessani & Harris, 2018), in that order.

2.6. Questionaires

The GREEN Scale (Haws et al., 2014) measures the tendency to express the value of environmental protection through one's purchases and consumption behaviors. (e.g., "It is important to me that the products I use do not harm the environment"). Participants were required to rate these items on a 7-point Likert scale from 1 (strongly disagree) to 7 (strongly agree).

The Climate Change Beliefs questionnaire (CCB) developed by (Jessani & Harris, 2018) was included to measure climate change beliefs. This questionnaire assesses three types of beliefs about climate change (belief that climate change is a problem, belief that climate change is anthropogenic, and that individual behavior can help control climate). Participants were presented with 17 statements (e.g., "I try to make choices that will limit climate change") that must be rated from 1 (strongly disagree) to 7 (strongly agree).

The footprint illusion task and the two questionnaires were presented as a web application based on World Wide Web Consortium (W3C) standards (i.e., HTML, CSS, and JavaScript). Participants were required to use a desktop computer and the Google Chrome browser to ensure compatibility. A demonstration of this task can be downloaded from the Open Science Framework.

3. Results

3.1. Footprint impact ratings

As we have explained above, impact ratings can be interpreted as estimations of the perceived causal effect on the carbon footprint that is produced by introducing the new houses in the second phase. That is, they serve to describe how people represent the causal effect of adding either green (experimental group) or regular (control group) houses on the carbon footprint of the community. Fig. 5 depicts the ratings about the new houses' impact on the household carbon footprint in the experimental and control groups. As we expected and in accordance with the data that we showed them, most participants considered that new houses increased the household carbon footprint. Accordingly, averaged impact ratings were significantly higher than zero in both groups ($M_{\text{Control}} = 35.98$, $t(92) = 10.20$, d=1.06, $p < 0.001$; and $M_{Experimental} = 26.03$, $t(105) = 8.27$, d=0.80, $p < 0.001$). However, impact ratings were significatively higher in the control group than in the experimental group, $t(197) = 2.11$, $p = 0.036$, $d = 0.30$, 95 % CI [0.02, 0.58]. That is, those participants that were not informed about the environmental certification of the new houses considered that these houses increased the household carbon footprint to a higher extent than those participants that were told that the houses were eco-friendly, which is consistent with an eco-labellingeffect described above.

3.2. Carbon footprint estimations

To further explore the effect of presenting the new houses as "environmentally certified" and "eco-friendly", we analyzed the household carbon footprint estimations before and after the new houses were built on each group (see Fig. 6). A footprint illusion can be detected in the experimental group if carbon footprint estimations of regular and environmentally friendly houses in combination are lower than estimates of the regular houses alone. Aditionally, an eco-labelling effect on information encoding an retrieval can be also detected by measuring accuracy of footprint estimations.

A mixed ANOVA including Phase (A and A + B) and Group (experimental and control) as factors was carried out on the household carbon footprint estimations. This analysis showed a significant main effect of Phase, $F(1,197) = 151.10$, $p < 0.001$, $\eta_p^2 = 0.43$, 95 % CI [0.33, 0.51] with lower values for the first phase (before the new housed were built) than for the second (after the new houses were built), $M = 60.71$, SD = 6.61 and $M = 67.18$, SD = 6.48 respectively. The remaining effects and interactions were not significant. These results show that, overall, participants perceived the increase in the household carbon footprint once the new houses were built (i.e., A + B > A), and that this increase was similar in both groups (experimental and control).

Fig. 6 shows also that participants gave accurate estimations of the mean values to which they were exposed during the training phases. In

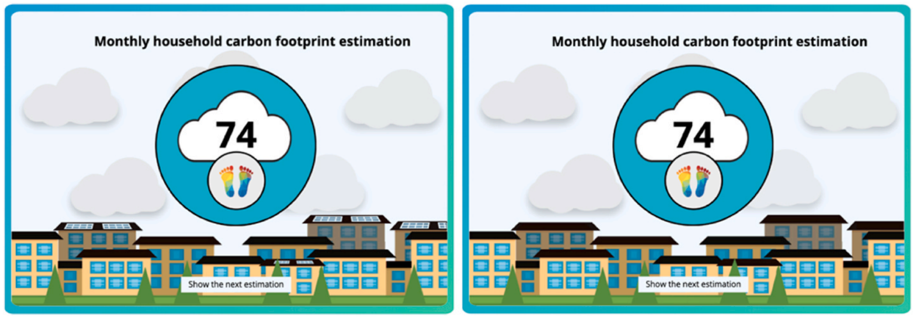

Fig. 3. Screenshots of the pictures used along the A + B Phase for Experimental (left) and Control (right) group. Note the solar panels in the roofs of new houses.

fact, no differences were found between the actual programmed values, and the participants' averaged estimations, neither for Phase A (programmed value $M = 61$), $M = 60.71$, $t(198) = -0.61$, $p = 0.54$, $d = -0.04$; nor for Phase A + B (programmed value $M = 67$), $M = 67.18$, $t(198) = 0.38$, $p = 0.70$, $d = 0.03$. These results evidence that participants in both groups encoded and retrieved the training information accurately.

3.3. Environmental concern and negative footprint illusion

As mentioned above, we included the GREEN Scale (Haws et al., 2014) and the Climate Change Beliefs questionnaire (CCB; Jessani & Harris, 2018) to measure and to control for environmental concern. We did not find significant differences in these questionnaires between experimental and control groups that may explain any of the effects reported above (see Table 2).

We did find a positive correlation between GREEN scale and CCB, Pearson's r=0.51, $p < 0.001$, 95 % CI [0.39, 0.60]. All dimensions of the CCB were significatively correlated with the GREEN scale, Pearson's r=0.38 [0.26, 0.50], 0.39 [0.27, 0.51], and 0.62 [0.52, 0.70], respectively for the belief that climate change is a problem, that climate change is anthropogenic, and that individual behavior can help control climate (all $ps < 0.001$). This is not a surprising result given that beliefs about climate change are expected to partly underly green consumption behavior, that is, those participants concerned with climate change and who consider that humans have a role on it, are expected to exhibit a greener behavior as consumers.

Including CCB and GREEN scale scores as covariates in the analysis of the impact ratings and household carbon footprint estimations did not change the pattern of results reported so far. The effect of group on impact ratings held when controlling by these two measures, $F(1, 195) = 4.33$, p= 0.039, $\eta_p^2 = 0.02$ [0, 0.076], and so did the effect of phase on carbon footprint estimations, $F(1,195) = 5.62$, $p = 0.019$, $\eta_p^2 = 0.03$ [0.001, 0.09]. In this second analysis, we also found a main effect of CCB scores, $F(1,195) = 6.04$, $p = 0.015$, $\eta_p^2 = 0.03$ [0.001, 0.09]. Follow-up analyses showed a positive correlation between household carbon footprint estimations and CCB scores (Pearson's $r = 0.19$ [0.05, 0.32], $p < 0.007$, and Pearson's $r = 0.15$ [0.02, 0.29], p=0.030, respectively for the estimations before and after the new houses were built). Further analyses carried out to explore this relation showed that only two dimensions of the CCB were related to these estimations: those referred to the belief that climate change is a problem (Pearson's $r = 0.23$ [0.09, 0.35], $p = 0.001$, and Pearson's $r = 0.17$ [0.03, 0.30], $p = 0.018$ respectively for estimations before and after the new houses were built) and those referred to the belief that the climate change is anthropogenic (Pearson's $r = 0.18$ [0.04, 0.31], $p = 0.011$, and Pearson's $r = 0.15$ [0.01, 0.28], $p = 0.040$ respectively for estimations before and after the new houses were built).

4. Discussion

This experiment explores how people perceive the environmental impact of houses labelled as eco-friendly. We found that individuals tend to judge the carbon footprint of eco-friendly labelled houses as lower compared to houses without label, indicating an effect of eco-labelling. What is novel is that this biased perception occurs even when participants are exposed to information that should, in principle, assist them in making accurate and unbiased judgments. This suggests that the bias lies in the elaboration of the causal belief about how the new houses impact the environment. Previous research suggests that eco-labeling acts as a salient cue that influences judgments of the perceived environmental impact of consumer behavior. In this context, Sörqvist et al. (2024a, 2024b) recently demonstrated that memory biases, such as recency effects, can affect how individuals assess the environmental impact of a sequence of products when labelled items are included. Thus, Sörqvist et al. (2024a) found that valuations of the environmental impact of sequence of shopping items were more favorable if the sequence ended with an eco-labelled item in comparison with other type of sequences without labelled items or with labelled items at the beginning or in the middle of the sequence. Sörqvist et al. (2024b) also found this recency effect in item sequences using a procedure in which participants were presented with sequences of different houses that varied in the amount of CO_2 (in kg) that they generated. After each sequence, participants were required to estimate the total CO_2 emissions of the houses in that sequence (providing a response between 1 and 100 kg of CO_2). Their results showed that when sequences ended with a low carbon footprint item, the total sequence was judged as having a lower carbon footprint than similar sequences with identical items but presented in a different order. Overall, the findings by Sörqvist et al. (2024a, 2024b) highlight the role of memory biases in judgments about the environmental impact of sequentially presented items. Specifically, serial position effects (i.e., recency effects) appear to prominently emerge, influencing the perceived environmental impact of the complete sequence.

However, while our results converge with Sörqvist et al. (2024a, 2024b) in showing how eco-labels can guide information processing, they do not align with memory biases.[1] In fact, when participants in our study were asked to estimate the carbon footprints for the initial set of houses (A) and the later, larger set (A + B), their responses were accurate in both groups, indicating that the information presented was correctly perceived and recalled independent of the eco-label. This result allows us to discard a problem in information encoding or retrieval as an explanation of the biasing effect of eco-friendly labels on the perceived impact. More generally, it makes our results compatible with the idea

[1] *Note that our design controls for the specific recency effects mentioned in the previous paragrapg by (1) presenting phases on a fixed order (when green houses are presented, they are always showed on phase 2, that is, at the end of the sequence); and by (2) randomizing the order in which the items (carbon footprint values) are presented to each participant, so that the effect of specific sequences is controlled for at the aggregate level.*

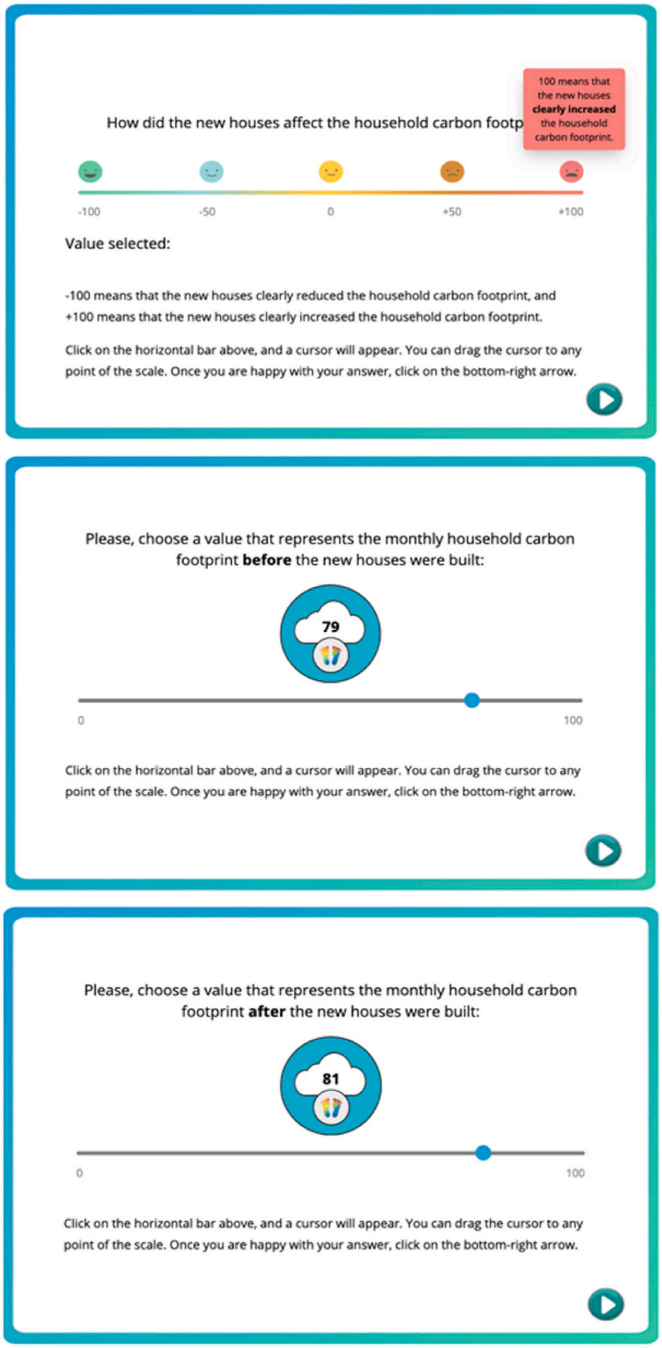

Fig. 4. Interactive visual scales used to assess the estimated impact of new houses on the community household carbon footprint (impact ratings, top panel) and the monthly community household carbon footprint estimations before and after the new houses were built (carbon footprint estimations, middle and bottom panels).

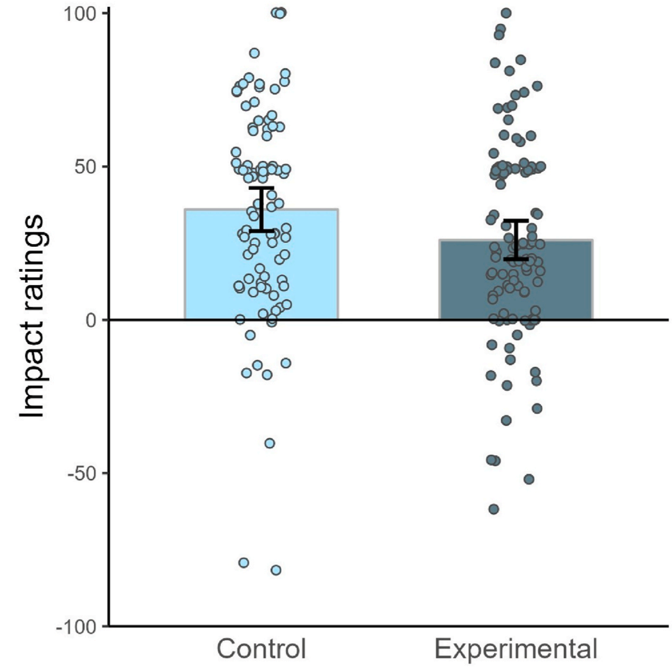

Fig. 5. Mean impact ratings in Experimental and Control groups. Error bars depict the 95 % confidence intervals for the means. Points represent impact ratings of individual participants (horizontal jitter was added to each point to reduce overlapping).

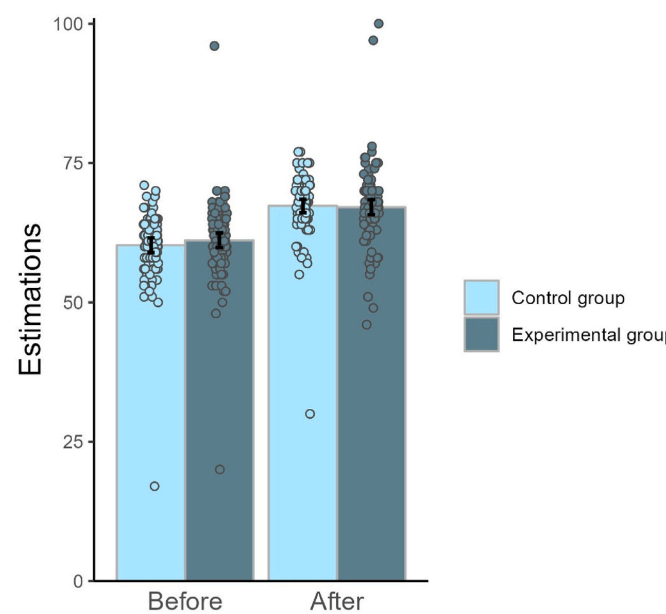

Fig. 6. Mean household carbon footprint estimations before (left panel) and after (right panel) the new houses were built. Error bars depict the 95 % confidence intervals for the means. Points represent impact ratings of individual participants (horizontal jitter was added to each point to reduce overlapping).

that causal inferences are influenced not only by the actual information to which participants are exposed, but also by their expectations and beliefs system (Blanco et al., 2018; Vicente et al., 2023). That is, despite participants correctly learning the contingencies they were exposed to (as carbon footprint estimations indicate), their expectations about the new eco-friendly labelled houses biased their judgments about the causal effects (i.e., the impact ratings).

Thus, impact ratings were clearly biased by the ecological labels and descriptions of the houses. That is, participants judged the impact on A + B phase to be smaller in the experimental group (with eco-labels) than in the control group (without eco-labels). This happened even despite: (a) the actual information about the footprints was available during training, (b) this information was identical for all participants irrespective of their group, and (c) participants were able to accurately learn and recall the actual values of the footprints. This idea can be connected to several theoretical proposals that represent causal learning as a dual process, in which information can be acquired correctly during the training phase, but inferences on this information can be affected by other variables and sources of information (e.g., emotions, motivation,

Table 2
Comparison of group performance on the GREEN Scale and the CCB questionnaire.

	Group	Mean	SD	*t* (197)	*p*	*d*
GREEN Score	Control	29.25	7.29	−1.54	0.126	−0.22
	Experimental	30.88	7.62			
CCB Score	Control	99.45	16.92	0.35	0.727	0.05
	Experimental	98.68	14.28			
CCB Problem	Control	6.07	1.09	−0.01	0.995	−0.00
	Experimental	6.07	0.89			
CCB Anthropogenic	Control	5.93	1.07	1.05	0.294	0.15
	Experimental	5.77	1.01			
CCB Control	Control	5.31	1.13	0.00	0.997	0.00
	Experimental	5.31	1.13			

Note: CCB Problem, CCB Anthropogenic and CCB Control refers to the three dimensions of the CCB.

expectations, attitudes), thus producing deviations in the judgments (Allan et al., 2005; Fugelsang & Roser, 2010; Fugelsang & Thompson, 2001; Fugelsang & Thompson, 2003). Some researchers propose that the mechanism by which these variables affect the judgment is the differential weight given to the various types of information (e.g., greater weight to confirmatory information or information that is congruent with prior beliefs; Catena et al., 1998; Mandel & Vartanian, 2009; Wasserman et al., 1990). Investigating the strategies that participants rely on when interpreting the carbon footprint information could provide deeper insights into the bias reported here. On the other hand, we did not find evidence supporting a negative carbon footprint illusion of green-labelled houses, that is, most participants correctly judged that the new houses increased the household carbon footprint with respect to the initial set (i.e., they correctly realized that A + B > A). This result suggests that, even though labels have an effect on impact ratings as explained above, facing participants with information about the environmental impact of our actions may help to eliminate the negative footprint illusion. That is, at least in our laboratory procedure, providing accurate information about the actual impact of an action seems to be enough to prevent the negative footprint illusion, and therefore it may be considered as an effective strategy for preventing its potential influence on decisions that can cause harm to the environment (Hope et al., 2017).

As we mentioned in previous sections, our procedure was inspired in the standard task used to study causal learning. This is because we assume that people's decisions and judgments about the effectiveness of actions and measures to address climate change are based on causal beliefs. That is, the implication is that, if a certain measure has a causal relationship with environmental conditions, then when the measure is implemented (e.g., building sustainable houses) we should observe a subsequent environmental effect (e.g., a reduction in the carbon emission levels). Moreover, people can use this information to learn whether the measure was causally effective. Consequently with this parallel with the causal learning literature, our main dependent variable, impact ratings, essentially measures how strongly participants believe that building new houses affects the carbon footprint (therefore, impact ratings are similar to causal judgments used in the causal learning literature). What is notable in our experiment is that all participants are presented with the same information to estimate causality (i.e., the same increase in carbon emissions), but we found more favorable impact ratings when the buildings are presented as eco-friendly. This can be framed as a misestimation of causality that resembles some results in the causal learning literature (e.g., the illusion of causality, Matute et al., 2015, Moreno-Fernandez et al., 2023).

Thorough this paper, we have interpreted our result as an "eco-labelling effect". Participants were told that new buildings received an ecological label, but they were not explicitly instructed as to what the label meant (e.g., it could be that the buildings produce fewer emissions, but also that they were manufactured in a sustainable way). Participants just assumed that because of this label, new buildings should have a smaller impact on the carbon footprint. Thus, the label seems to have worked as a heuristic. Additionally, because the footprint estimations were in general accurate, the labelling effect seems to work by systematically biasing the percieved environmental impact. However, there are other ways in which the label can affect congition that are not directly assessed in this experiment. Further studies could, for instance, collect additional judgments about other attributes of the buildings (e.g., comfort, aesthetics …) unrelated to environmental impact, so that we could investigate whether the labelling effect extends to a "green halo" effect (Sörqvist et al., 2015).

In sum, this experiment shows than under circumstances where ecological labels generate biased expectations about sustainability through a eco-label effect, providing information regarding the actual carbon footprint of such products may positively contribute to prevent the tendency to overestimate their positive impact. Therefore, providing information on the actual carbon footprint of products can be deemed as a valuable tool to debias and prevent the false sense of success in reducing environmental impact of green labels through a the negative footprint illusion.

5. Limitations and future research

An important consideration in our study is related to the way in which the environmental impact was conveyed. In this study, we informed participants that they would be presented with information of the combined household carbon footprint, ranging from 0 (very low impact) to 100 (very high impact). While the use of this truncated scale without meaningful units was effective for the purposes of our experiment, we acknowledge that it may limit the ecological validity of the task. However, the alternative of presenting carbon footprint information in a more realistic way (e.g., in kilogram carbon dioxide emission) would have been extremely challenging within the context of this task, and it would probably have been harder for participants to understand. Thus, our choice was based on methodological and practical considerations, as we aimed to provide participants with an easily understandable and memorable environmental impact estimate, with clear bounds. The scale allowed participants to assess whether the impact was high or low based on the range of possible values, which helped reduce uncertainty when making judgments about the environmental impact of the new houses. Given these challenges, the use of an artificial scale appeared more appropriate although we acknowledge that this approach has implications for external validity because it does not reflect the complexity of real-world carbon footprint data. Future research could explore alternative methods, such as providing more realistic carbon footprint information, to enhance both the ecological validity and generalizability of the findings. Additionally, these studies must address the challenge of ensuring that labels and numerical data, such as carbon footprint metrics, are interpreted in a meaningful and accessible way.

Additionally, it is important to note that assessing the sustainability of a product based solely on metrics such as carbon footprints is not easy for consumers (see Beyer et al., 2024; Thøgersen & Nielsen, 2016). In fact, these numerical data and labels are used to summarize, and thus simplify, complex realities such as environmental impact. The bias we report could be considered as a side-effect of pursuing this goal, because consumers could rely on the label without fully understanding what it represents or how certification schemes operate (Grunert et al., 2014, Donato & D'Aniello, 2022; Hornibrook et al., 2015; Thorsøe et al., 2016). That is, consumers could use eco-labels as a heuristic, a simple cue to guide their decisions without entirely appreciating their implications. This may eventually create a barrier to informed consumer action, fostering biases like the one described in this study. Therefore, researchers and policy makers should consider ways to improve the effectiveness of eco-labels, by enhancing transparency, educating consumers about their meaning or integrating additional mechanisms to mitigate the biases they can induce.

Another aspect of our research that deserves further explanation relates to our choice of the trial-by-trial procedure. The trial-by-trial procedure implies that the information is presented sequentially and piece-wise. This attempts to simulate real-life learning, which typically unfolds incrementally through experience. Previous research has shown that different presentation formats (e.g., trial-by-trial vs. tabular summary) can influence the performance on tasks similar to the one used here (Cooper & Vallée-Tourangeau, 2021; Kao & Wasserman, 1993; Willett & Rottman, 2021; Aberman & Plaks, 2022), suggesting that people learn differently when presented with a summary of the information vs. a sequence of trials. In this particular experiment, we focused on the final outcome of the learning that can be observed at the end of the session, and hence we requested a global judgment rather than, for example, requesting a judgment at the end of each trial, which is another design choice. Although we motivate our decisions on an attempt to represent the process of learning in real-life scenarios, they open three possibilities for ture research. The first idea focuses on a detailed analysis of how the learning acquisition process evolves over time. In the current experiment, we were interested in the final judgment at the end of the session after sequentially incorporating all the information, but since we did not include trial-by-trial judgments we cannot examine the update process. Thus, future research may incorporate trial-by-trial judgments to allow for a more detailed analyses of learning curves. The second idea is to explore the potential effect of using different presentation formats in addition to the trial-by-trial procedure (e.g., summary formats: tabular, iconic, etc.). As we have argued, people probably learn differently from sequences and for summaries, and this could be affecting the results. Finally, the third idea is to explore the effect of trial-by-trial judgments as compared to global judgments, because previous research has also shown that trial-by-trial judgments might be more prone to recency effects than global judgments (see, e.g., Catena et al., 1998; Matute et al., 2002; Collins & Shanks, 2002). The findings from such studies could shed light on how presentation formats and frequency of judgments might help protect individuals from biases such as the one observed here, as well as from the sequential biases identified in previous research (see Sörqvist et al., 2024a, Sörqvist et al., 2013).

Additionally, it would be valuable to further explore the role of individual differences in moderating the effects reported here. Our results do not appear to be directly related to the measures of environmental concern included in the study. One possibility to explain this null finding is that environmental concern is not a relevant factor in the emergence of the specific biases related to green labelling that are reported here, or at least that its contribution is too small to be captured by our procedure. For example, we did not include a direct measure of climate change denial. While denial could be indirectly inferred from low scores on the CCB scales (Jessani & Harris, 2018), this approach does not fully reflect the explicit rejection of climate change. Future research should consider incorporating additional instruments that enable a more comprehensive measurement of environmental beliefs and attitudes, such as including specific items to directly assess climate change denial. This approach could provide a more nuanced understanding of how individuals' beliefs influence the effects of eco-labeling.

In addition to pre-existing beliefs related to environmental concern, there are other factors that could potentially contribute to biases associated with eco-labeling that have not been assessed in this study. For instance, prior research has highlighted the relevance of individual differences in information processing (e.g., García-Arch et al., 2024). Thus, the tendency to jump to conclusions (the inclination to quickly assume a relationship without sufficient evidence or consideration of alternative explanations) appears to be an individual trait that influences other biases, such as the illusion of causality (Moreno-Fernandez et al., 2021). In line with this, individuals who tend to jump to conclusions may prematurely conclude that a product is environmentally friendly simply because it has an eco-label, without considering other relevant factors. This could lead to overestimations of the product's actual environmental benefits, hence biasing judgments.

Yet another potentially important variable is numeracy, which has shown to be particularly relevant for predicting the effectiveness of debiasing interventions based on providing data. Thus, individuals with higher ability to understand and operate with numbers should be better equipped to process and make informed decisions based on numerical data, which would improve the impact of such data-based interventions (Budescu et al., 2014; Cho et al., 2024; Hart, 2013). However, this also raises the issue of individuals with lower numeracy skills, who may struggle to interpret or critically assess the provided data, potentially limiting the effectiveness of these interventions for that group. Future research could directly address the role of these factors.

One final limitation we would like to mention is that our study employs a control group without a label, allowing for the possibility that the reported effects are driven by the salience of the label rather than its specific content (i.e., we cannot be entirely certain to what extent this effect is driven by the mere presence of a label and to what extent it is influenced by its specific meaning). Future studies could explore differences using control groups that also include labels (e.g., "Newly Built" or "Standard") to determine to what extent the eco-related nature of the label is responsible for the observed effects.

To sum up, the experiment we report here shows that, at least in some conditions, providing information to participants is not always enough to counter the biasing effect of eco-friendly labels, which can impact judgment. As we have argued, this study opens the possibility to further research other situations related to the perception of eco-labelled products and goods.

CRediT authorship contribution statement

María M. Moreno-Fernández: Writing – review & editing, Writing – original draft, Visualization, Software, Project administration, Methodology, Formal analysis, Data curation, Conceptualization. **Fernando Blanco:** Writing – review & editing, Visualization, Supervision, Funding acquisition, Formal analysis. **Helena Matute:** Writing – review & editing, Supervision, Funding acquisition.

Declaration of generative AI and AI-assisted technologies in the writing process

During the preparation of this work the authors used ChatGPT by OpenAI in order to improve languague and readability in certain specific sections of the manuscript. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Appendix A. Instructions

A Phase Instructions

[Screen 1]:
"A carbon footprint is the total amount of greenhouse gases that are generated by human actions: The higher the carbon footprint, the higher the environmental impact of human actions".
[Screen 2]
"Many of our daily activities cause emissions of greenhouse gases that make up the household carbon footprint. The household carbon footprint depends on many aspects such as the type of fuel used to generate the electricity at home, recycling behavior, home insulation, or the efficiency of domestic devices such as boilers, fridges or washing machines".
[Screen 3]
"In this experiment you will be presented with a series of estimations of the environmental impact that the 100 houses of one community have together, that is, an estimation of their combined household carbon footprint.
Each estimation will refer to one month, and they may range from 0 (very low impact) to 100 (very high impact). Please, pay careful attention as we will ask you some questions later."
[Screen 4]
"Have you understood the instructions well?
If you need to read the instructions again, please do it now, as you will not be able to return once you start the experiment".
[Screen 5]
Now you will be presented with the series of monthly estimations of the combined household carbon footprint that the houses of this community have.

A + B Phase Instructions

[Screen 1]
Underlined text was presented only to the experimental Group
"The community has decided to build 30 additional houses, all of which will be environmentally certified and eco-friendly.
Next you will be presented with a series of estimations of the combined household carbon footprint that the houses of this community have when the additional environmentally certified houses have been built. As previously, each estimation will refer to one month, and they will range from 0 (very low impact) to 100 (very high impact)".

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