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Underestimations of the income-based ecological footprint inequality

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Abstract
Previous research has demonstrated that the wealthy harm the environment to a much greater extent than those with lesser means. According to recent estimates, the wealthiest 1% of the world's population emit 50% more CO2 than the bottom half of the income distribution. The reason for this inequality is clear: affluence boosts consumption, which in turn increases the ecological footprint. Although the phenomenon seems intuitive, little is known as to whether the layperson notices it. The current study assesses the extent to which individuals recognize or fail to notice such massive ecological footprint inequality and why misperceptions may arise. Across four preregistered studies (N = 1,188) conducted in a highly unequal socio-economic environment (Brazil), we show that people often fail to accurately perceive the meaningful ecological footprint inequality that surrounds them. These misperceptions are explained by people's (a) failure to properly incorporate the impact of income-based differences in consumption in their ecological footprint assessments and (b) tendency to associate wealth with superior environmental education, greater resources to act sustainably, and better local infrastructure (e.g., cleaner paved streets and proper waste collection). Emphasizing the lack of infrastructure in deprived neighborhoods further exacerbates the misperceptions, whereas highlighting key differences in consumption habits across the socio-economic spectrum increases accuracy. This research, thus, identifies the factors that magnify existing misperceptions in ecological footprint inequality and provides avenues for policymakers to reduce such mistakes.

Keywords Ecological Footprint Inequality · Carbon Inequality · Income and Environmental Impact · Environmental Perceptions · Sustainability

1 Introduction

Climate change is one of the most pressing challenges of our time (Ripple et al. 2017; Steffen et al. 2015). At the center of the climate urgency is the increase in the consumption of natural resources over the past decades. According to estimates from the United Nations, the global material footprint—i.e., the amount of raw materials extracted to meet consumption demands—more than doubled between 1990 and 2017 (United Nations,

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2019). Although progress has been made toward the development of environmental policies and technological solutions, sustainable development can only be achieved if changes in individual lifestyles complement governmental and scientific advancements (Intergovernmental Panel on Climate Change 2021; Wiedenhofer et al. 2020).

Humans, however, do not harm the environment equally. Research has consistently demonstrated that the wealthy display a much greater ecological footprint than their lower-income counterparts (Wiedmann et al. 2020). The presence of a meaningful ecological footprint inequality is visible irrespective of target footprint (e.g., water, carbon, or energy), measurement strategy (e.g., consumption and emissions assessed via self-reports or objective footprint calculations), sample (e.g., data from developed or developing countries), or unit of analysis (e.g., comparisons within or across countries; Baltruszewicz et al. 2023; Hubacek et al. 2017; Oswald et al. 2020; Wahba 2021). The effect is acutely noticeable at the extremes of the income distribution (Hubacek et al. 2017). Bruckner and colleagues (2022) demonstrated that 50% of the global population contributes only 10% of the total carbon emissions, while the top 1% contribute to an astonishing 15%. Intranational data reveals a similar reality. In fact, within-country disparities nowadays contribute more to global carbon emissions inequality than cross-country variations (Chancel et al. 2023). This inequality seems particularly pronounced in developing nations. Oswald and colleagues (2020) showed that in regions where income inequality is high, such as Latin America and Sub-Saharan Africa, energy footprint inequality tends to be even larger.

While the actual footprint inequality has been well documented, it remains unclear the extent to which the layperson notices it. Recent evidence shows that people often fail to recognize that low-income individuals are particularly affected by the *consequences* of the current climate crisis (Schuldt & Pearson 2023). However, it is unknown the extent to which people recognize the income-based inequalities related to the *causes* of climate change. This research investigates whether lay people hold inaccurate perceptions of the environmental impact caused by high- and low-income individuals, and, if so, what drives such misperceptions and what are the means to correct them. Addressing these questions is important. If people do not notice this massive footprint inequality, higher-income individuals will not hold themselves accountable for their disproportionate contribution to the climatic crisis. They will also often fail to recognize that their high levels of consumption are particularly harmful to the environment. These are arguably two critical preconditions for the wealthy to adopt more sustainable lifestyles and restrain rather excessive consumption patterns.

On the one hand, the rationale behind ecological footprint inequality seems intuitive. Because affluence induces abundant consumption, and consequently greater use of natural sources and sinks, one could reasonably expect the average wealthy individual to place a much greater burden on the environment than their deprived counterpart. On the other hand, there are theoretical reasons to suspect that the phenomenon may not seem obvious to the layperson. First, when comparing the ecological footprint of the wealthy versus those more disadvantaged, quantity insensitivity may lead individuals to overlook the impact of the marked differences in consumption patterns across the income spectrum, and thus underestimate this footprint inequality (Kim and Schuldt 2018; Stadelmann and Schubert 2018). Further, some associations may even nudge the individual to intuitively believe that the low-income segment harms the environment at least as much as their high-income

counterparts. Compared to the wealthy, the destitute are less educated, have fewer financial resources, and live in areas characterized by stronger visual and auditory pollution, which may suggest that they are less concerned about and/or knowledgeable of environmental challenges, less capable of purchasing sustainable alternatives (which are often more expensive; Benveniste 2019; Bonsu 2021), and less careful with the cleanliness of their surroundings.

Across four preregistered studies conducted in Brazil, we are the first to assess (i) potential misperceptions of ecological footprint inequality and (ii) the extent to which the previously mentioned mechanisms drive these inaccuracies. Brazil's significant and highly visible disparities in the income (Hecksher et al. 2018), and, consequently, in the ecological footprint (Zhong et al. 2020), along with relatively low levels of environmental education (Wolf et al. 2022), present an ideal social environment to assess the extent to which the intuitive footprint misperceptions emerge, even when the extreme poles of the income distribution are directly contrasted. On a more substantive front, investigating people's (mis) perceptions of such massive ecological footprint inequality, the factors driving these inaccuracies, and what can be done to correct them may help increase accountability and social pressure, and hopefully establish new consumption norms among the affluent. Finally, our research converges with recent appeals for more behavioral research that investigates perceptions and inequities associated with climate change (Pearson et al. 2023).

2 Literature review

Research has consistently demonstrated that people often hold perceptions that depart from objective reality (Frederick 2012; Jung et al. 2020; Robinson et al. 1995). For example, humans tend to interpret personal events more positively than is justified by objective standards (unrealistic optimism; Vieites et al. 2021; Weinstein 1980), mistakenly view one's attitudes and behaviors as rather prevalent (false consensus effect; Mullen et al. 1985), and perceive outgroup members as more similar to one another than ingroup members (outgroup homogeneity bias; Park and Rothbart 1982). Such theories have been widely applied to explain judgments and behaviors across multiple domains (e.g., the formation of political opinions and mask-wearing practices against COVID-19; Rabinowitz et al. 2016; Vieites et al. 2021).

Several perceptual biases have also been documented in the domain of climate change and sustainability. For example, even though conventional products may hold the same quality as their sustainable alternatives, people often perceive the latter as having lower quality (sustainability liability effect; Luchs et al. 2010). People also tend to erroneously estimate the total environmental impact of combinations of green and non-green products as lower than the same non-green product alone, a phenomenon referred to as the negative footprint illusion (Gorissen and Weijters 2016). Relatedly, people perceive plastic packaging with additional paper to be more environmentally friendly than identical plastic packaging without paper (Sokolova et al. 2023). Thus, although previous research has identified several types of sustainability-related misperceptions, they generally apply to material goods and their packages. We extend this research by investigating the existence of misperceptions that apply to the lifestyles of different social groups. More specifically, we investigate whether and why people hold inaccurate perceptions about the relative environmental impact of high- and low-income individuals.

While it is possible that individuals accurately perceive this meaningful footprint inequality, there are reasons to believe this is not the case. First, even if people hold the correct affluence-consumption-footprint theory, they may not consider it critical in determining the existing footprint inequality. Indeed, people tend to display a quantity or scope insensitivity, whereby they neglect the impact of volume in everyday purchase decisions (Chang and Pham 2018; Kim and Schuldt 2018; Stadelmann and Schubert 2018). To illustrate, when comparing the environmental impact of different options of home appliances, consumers give disproportionate weight to the energy efficiency of the product and overlook their occasional substantial size differences (Stadelmann and Schubert 2018). By the same token, it is possible that when comparing the ecological footprint of high- and low-income individuals, people may overlook the massive differences in the levels of consumption across the socio-economic spectrum, and ultimately underestimate the magnitude of the footprint inequality between the haves and have-nots.

Further, some associations may lead the layperson to believe that the destitute have a similar or even larger impact on the environment. Compared to the wealthy, impoverished individuals are less educated, which may suggest that they are less concerned about and/or knowledgeable of environmental challenges and possible solutions (Franzen and Meyer 2010; Gelissen 2007). Indeed, education is often portrayed as an important avenue to promote the widespread adoption of more sustainable practices, and a lack of formal schooling may be interpreted as a barrier to sustainability.

Low-income individuals also have fewer financial and time-related resources, which may indicate that it is more costly for them to act sustainably (Pieters et al. 2022). This is particularly relevant to the multiple contexts in which the green act is more expensive (e.g., buying an electric vehicle, purchasing local/organic food, installing solar panels at home, etc.; Benveniste 2019; Bonsu 2021).

Finally, the urban areas where most of the world now lives (United Nations 2018) tend to display startling differences across the socio-economic spectrum. Due mostly to governmental failures in the provision of infrastructure services, urban low-income people tend to live in areas characterized by stronger visual and auditory pollution–areas that are often dirtier and deprived of green (e.g., slums)–, whereas the affluent tend to live in cleaner and greener communities (Astell-Burt et al. 2014; Spotswood et al. 2021). Given people's tendency to attribute outcomes to dispositional characteristics instead of contextual factors (Harvey et al. 1981; Ross 1977), observers may picture the destitute as less careful with the cleanliness of their surroundings. Thus, the direct associations between wealth and cleanliness and between poverty and proximal pollution can make the finding that the wealthy are the ones who harm the environment the most less intuitive.

In short, whereas the effect of affluence on consumption patterns, and consequently, on ecological footprint is clear (Hubacek et al. 2017; Oswald et al. 2020; Wahba 2021; Wiedenhofer et al. 2017), we hypothesize that many individuals may not notice the meaningful ecological footprint inequality that surrounds them because of their (1) failure to properly incorporate the impact of income-based differences in consumption patterns on their ecological footprint estimates and (2) tendency to associate poverty with lower environmental education, fewer resources to act sustainably, and greater proximal pollution.

3 Overview of the studies

We conducted a series of four studies to test the hypothesis that individuals fail to perceive the massive income-based ecological footprint inequality. We also investigated the mechanisms underlying such potential misperceptions. Table 1 summarizes the sample of each study, their design, the specific dependent measures employed, the statistical tests conducted to examine the hypotheses, and the main findings. All studies were conducted in Brazil, a highly unequal country with a prominent role in the global climate agenda. Participants were recruited via Netquest, a large and diverse online panel.

We relied on surveys to assess people's perceptions of relative environmental harm across the socioeconomic spectrum and experiments to systematically examine the mechanisms that may guide such (mis)perceptions. In doing so, we were able to capture people's baseline views while also providing causal evidence for the factors that exacerbate or attenuate such views. Our studies were devised to avoid hypothesis guessing and demand effects, as we tried to mask the purpose of the studies throughout the empirical package (Mummolo and Peterson 2019). Further, we used three distinct dependent variables to measure perceived footprint inequality (i.e., environmental harm, environmental pollution, and global warming) to provide evidence for the robustness of our findings while also warding off potential concerns regarding specific lexical choices.

Studies 1 (N = 339) and 2 (N = 347) document baseline perceptions of income-based footprint inequality and uncover explanations for the phenomenon using survey methods. In studies 3 (N = 296) and 4 (N = 206), we employ experiments to further examine the mechanisms through which participants based their reasoning.

All studies were approved by the Institutional Review Board of Fundação Getulio Vargas (reference number: CEPH/FGV 221/2021). We used the software Stata 18.0 to analyze the data. All data and codes used in the studies are available in the Open Science Framework (OSF): https://osf.io/8g436/?view_only=fb5e41269d8f422d82d56ccaed7cf7c5.

4 Study 1: Misperceptions of ecological footprint inequality

Study 1 examines the existence of footprint inequality misperceptions and explores possible explanations for the phenomenon.

4.1 Method

4.1.1 Participants

In the absence of a clear benchmark for footprint perceptions, we used the average effect size in social psychology (d = 0.43; Richard et al. 2003) in our power analysis. Detecting such an effect with 95% power and an alpha level of 0.05 required a sample size of at least 236 participants. To maximize power, and consider potential exclusions, we recruited 356 Brazilian participants through an online panel. Seventeen participants failed the attention check and were removed from the analyses, which yielded a final sample of 339 respondents (Mean $(M)_{Age} = 40$ years, Standard Deviation $(SD)_{Age} = 13.21$; 53% male). The descriptive statistics of all studies are presented in the Supplementary Materials (Table S1).

Table 1 Overview of the Studies

Study	Sample	Design	Dependent Variables	Statistical Tests	Main Findings
1	N = 339 recruited from an online panel	Survey	Who has behaviors and lifestyles that harm the environment the most [pollute the environment the most/ contribute to global warming the most]: - *People with higher income; people with lower income; equal; I don't know*	Proportion test comparing % of accurate responses ("People with higher income") to 50%	Significantly less than 50% of participants (37.76%) displayed accurate perceptions about the widespread ecological footprint inequality ($z = -9.30$, $p < 0.001$)
2	N = 347 recruited from an online panel	Survey	Who has behaviors and lifestyles that harm the environment the most [pollute the environment the most/ contribute to global warming the most]: - *5-point scale (1 = prototypical poor individual much more; 5 = prototypical rich individual much more)*	One-sample t-test comparing mean of responses to accurate responses ("5 = prototypical rich individual harms/ pollutes/contributes to global warming much more")	The mean perception of ecological footprint inequality was much lower than the "strictly correct" response ($M = 3.13$, $SD = 1.11$; contrast to scale point 5: $t(346) = -31.28$, $p < 0.001$)
3	N = 296 recruited from an online panel	Experiment: Single factor, between subjects (Proximal pollution: control vs. treatment)	Who has behaviors and lifestyles that harm the environment the most? - *5-point scale (1 = prototypical poor individual hams much more the environment; 5 = prototypical rich individual hams much more the environment)*	Independent samples t-test comparing control and the salient proximal pollution conditions	Misperceptions of ecological footprint became even more pronounced in the salient proximal pollution condition ($M_{Proximal} = 2.82$, $SD = 1.17$ vs. $M_{Control} = 3.31$, $SD = 1.15$; $t(294) = 3.57$, $p < 0.001$)

Table 1 (continued)

Study	Sample	Design	Dependent Variables	Statistical Tests	Main Findings
4	N = 206 recruited from an online panel	Experiment: Single factor, between subjects (Income-based differences in consumption: control vs. treatment)	Which of these groups has behaviors and lifestyles that pollute the environment more? - *5-point scale (1 = lower-class individuals pollute the environment much more, 5 = higher-class individuals pollute the environment much more)*	Independent samples t-test comparing control and salient consumption conditions	Misperceptions were significantly attenuated when participants were prompted to class-based consumption questions ($M_{Control} = 3.06$, $SD = 1.14$, $M_{Salient\ Consumption} = 3.47$, $SD = 1.37$; $t(204) = 2.31$, $p = 0.022$)

4.1.2 Procedure

The sample size, hypotheses, and analysis plan were pre-registered at AsPredicted (https://aspredicted.org/X72_15B). In a 10-min online survey, participants were asked to spontaneously intuit about the relationship between income and environmental impact (our main dependent variable). For the sake of robustness, three versions of the focal question were created and randomly assigned among participants. Precisely, they were asked the following question:

> *"Who has behaviors and lifestyles that harm the environment the most [pollute the environment the most/contribute to global warming the most]: __people with higher income, __people with lower income, __equal, or __I don't know."* [freely translated from Portuguese].

The focal question was embedded in a list of 25 questions about the behaviors of different social groups. The remaining 24 filler questions varied either the behavior of interest (e.g., "Who watches television more?", "Who spends more time on social media?") and/or the social group/socio-demographic variable of interest (e.g., "Men vs. women", "younger vs. older adults"). These filler questions served to mask the main purpose of the study and avoid demand effects (a common source of concern in experimental research; Mummolo and Peterson 2019). The order of the filler items was randomized, with the focal question always presented halfway through the questionnaire. See Supplementary Materials 2.1 for details on the survey procedure.

After answering these 25 questions, participants were asked to justify their responses to our main focal question and the television-related filler question. Following the pre-registration, the textual justification for the focal question was systematically coded by two independent coders to assess the presence and influence of the advanced psychological mechanisms on the participants' perceptions (See Supplementary Materials 2.2 for details on the coding protocol).

Then, participants completed the following attention check "To demonstrate that you are paying attention to this questionnaire, please select only the option 'brand' from the choices below: price, style, quality, safety, brand, convenience, availability, value". Finally, they reported their gender, age, race, educational attainment (1 = no formal education, 11 = graduate degree), political orientation (1 = clearly left, 5 = clearly right), household income in Brazilian Reais (1 = less than R$500, 18 = above R$60,000; plus a Don't know/Refuse to answer option), number of people who depended on the reported income, and subjective income rank (1 = way below average, 5 = way above average).

4.2 Results and discussion

4.2.1 (Mis)Perceptions about footprint inequality

A one-sample proportion test contrasting the percentage of participants who provided the accurate response to the dependent variable against those who either provided an incorrect answer or reported not knowing the correct answer revealed that significantly less than 50% of participants (37.76%) displayed accurate perceptions about the widespread

ecological footprint inequality (z = -9.30 [95% CI 0.326 to 0.429], $p < 0.001$, standardized proportion = 0.78). The effect held irrespective of how the focal question was framed (all $ps < 0.001$). Figure 1 depicts the distribution of perceptions of ecological carbon footprint across the dependent variables.

4.2.2 Additional analyses

Pervasiveness of the phenomenon We explored the prevalence of ecological footprint misperceptions across different population subgroups. Providing evidence for the pervasiveness of the phenomenon, accuracy did not reach 50% in any of the subgroups (see Table S2 for detailed statistics of the prevalence of ecological footprint misperceptions across population subgroups).

Methodological considerations One could argue that the overall misperceptions were solely due to participants' inability or reluctance to form *any* opinion about income-based differences in ecological footprint. This is unlikely since only 12.68% of the original sample chose the option "I don't know" when assessing perceptions of relative ecological footprint. An exploratory one-sample proportions test excluding these participants revealed that people still held disproportionally more inaccurate (56.75%) than accurate perceptions (43.25%; z = -4.69 [95% CI 0.376 to 0.489], $p < 0.001$, standardized proportion = 0.87, Table S3). The misperceptions were also not due to people's unwillingness or inability to intuitively perceive differences across social groups in general. An analysis of the filler questions which compared the other social groups supports this assertion (Tables S4 and S5). For instance, participants displayed a strong intuition that men have a much greater ecological footprint than women (44% vs. 5%) and that the young have a much greater impact on the environment than their older peers (49% vs. 14%), even though there is no widespread scientific consensus to support these intuitions. In short, income-based differences in ecological footprint are massive and well-documented, yet many participants seem not able to intuitively form this impression when asked to.

Underlying mechanisms To assess the role of the proposed mechanisms related to perception formation about footprint inequality, two independent coders coded the

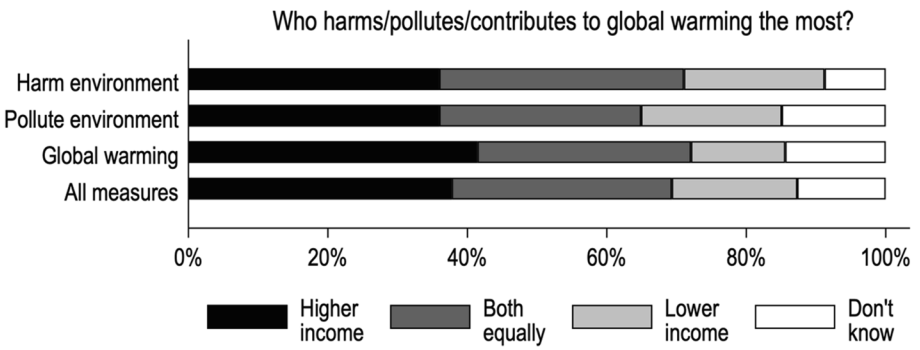


Fig. 1 Misperceptions of Ecological Footprint Inequality (Study 1). Distribution of perceptions of ecological carbon footprint across measures (environmental harm, environmental pollution, and global warming). "All measures" describes the results for the collapsed outcome variables. Raw proportions reported

participants' justifications (interrater agreement ranged from 83% to 97%; Supplementary Materials 2.2). The exploratory results showed that the apparently intuitive theory that would lead to the correct answer (i.e., affluence → consumption → ecological footprint) was not dominant in people's minds (see Table 2). Overall, only 28.32% of the participants reported that higher-income (vs. lower-income) individuals have a higher ecological footprint because they consume more. Inaccurate rationales which pointed to the opposite conclusion (i.e., lower-income individuals have a higher footprint) also emerged, though less frequently (20.94% [95% CI 0.166 to 0.253], $p = 0.042$, $d = 0.17$), while the belief that income had little influence on environmental impact was as common (26.84% [95% CI 0.221 to 0.316], $p = 0.704$, $d = 0.03$). Among those who indicated that the wealthier harm the environment more (N = 128, 38.76%) most did so based on the proper theoretical reasoning (69.53%; e.g., "more consumption = more pollution"). In contrast, most of those who reported that the poor harm the environment more (83.61%) relied on rationales related to (a) proximal pollution (e.g., "with a lack of basic sanitation, recycling programs, and piped water, the poor cannot contribute to improving the environment."), (b) lack of resources to act sustainably (e.g., "little access to sustainable options, both in food and in building a house, for example, due to the higher price of options that promote sustainability.") and/or (c) low environmental education (e.g., "in general, people with less income also have a lower level of education, consequently less concern for the environment.").

Table 2 Frequency of type of reasoning across responses

	Total (N = 339)		**Higher income more (N = 128)**		**Equal (N = 107)**		**Lower income more (N = 61)**		**I do not know (N = 43)**	
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**
Accurate reasoning: affluence-consumption-ecological footprint	**96**	**28.32%**	**89**	**69.53%**	**7**	**6.54%**	**0**	**0.00%**	**0**	**0.00%**
Inaccurate reasoning (1):	**71**	**20.94%**	**10**	**7.81%**	**8**	**7.48%**	**51**	**83.61%**	**2**	**4.65%**
Proximal pollution	17	5.01%	0	0.00%	2	1.87%	15	24.59%	0	0.00%
Resources to act sustainably	26	7.67%	9	7.03%	2	1.87%	13	21.31%	2	4.65%
Environmental education	35	10.32%	1	0.78%	4	3.74%	28	45.90%	2	4.65%
Inaccurate reasoning (2):	**91**	**26.84%**	**0**	**0.00%**	**83**	**77.57%**	**0**	**0.00%**	**8**	**18.60%**
No or little impact of social class	81	23.89%	0	0.00%	75	70.09%	0	0.00%	6	13.95%
Compensatory effects	11	3.24%	0	0.00%	9	8.41%	0	0.00%	2	4.65%
Inaccurate/Absent reasoning	**100**	**29.50%**	**31**	**24.22%**	**24**	**22.43%**	**10**	**16.39%**	**35**	**81.40%**
Do not know	33	9.73%	0	0.00%	3	2.80%	0	0.00%	30	69.77%
Other	47	13.86%	27	21.09%	12	11.21%	6	9.84%	2	4.65%
No answer/Illogical explanation	20	5.90%	4	3.13%	9	8.41%	4	6.56%	3	6.98%

The table shows coded justifications participants provided for their perceptions of ecological carbon footprint. Coding was made by two independent coders (interrater agreement ranged from 83 to 97%). The table considers the full sample (i.e., including participants who provided any response, including "don't know"). A given justification may have reflected multiple types of reasoning.

5 Study 2: Misperceptions of ecological footprint inequality with prototypical poor and wealthy individuals

Because Study 1 asks participants to compare people with "higher" versus "lower" income, it is possible that participants did not see the income differences across these two groups as striking enough to highlight the vast differences in consumption patterns, and hence the massive inequality in ecological footprint. Further, some participants may have incorporated population-level differences across them (i.e., there are more poor than wealthy people in the world), which in turn biased their judgments. Study 2 addresses these concerns by asking participants to compare the ecological footprint of a prototypical very poor individual to that of a very wealthy one. It also relies on an outcome measure that captures not only the direction (as did Study 1) but also the magnitude of the perceived ecological footprint inequality.

5.1 Method

5.1.1 Participants

Four hundred and fourteen Brazilians were recruited through Netquest. The sample size was calculated as in Study 1. Forty-four participants failed to report the dependent variables of ecological footprint inequality and 21 participants failed the attention check. Our final sample included 347 respondents (M_{Age} = 36 years, SD_{Age} = 12.70; 51% male).

5.1.2 Procedure

The sample size, hypotheses, and analysis plan were pre-registered at AsPredicted (https://aspredicted.org/H4G_YZ5). Participants read brief texts about a prototypical poor and a prototypical wealthy individual living in well-known neighborhoods that embody the dramatic socioeconomic inequality in Brazilian society (Jacob et al. 2022; Vieites et al. 2022):

> Prototypically poor individual: *"Maria/Ana is 40 years old, earns 1 minimum wage, and did not complete high school. She was born and still lives in Complexo de Favelas da Maré, one of poorest neighborhoods of Rio de Janeiro."*
> Prototypically wealthy individual*: "Ana/Maria is 38 years old, earns more than 20 minimum wages, and has graduated from college. She was born and still lives in Leblon, one of the wealthiest neighborhoods of Rio de Janeiro."* [freely translated from Portuguese].

The names of the prototypically poor and wealthy individuals were randomized between subjects. In other words, participants were randomly assigned to read descriptions of Ana or Maria as the prototypically poor (or wealthy) individuals. After reading the descriptions, participants were asked to answer five questions in the following order: two filler questions, the focal question, and two other filler questions.

As in Study 1, participants were randomly assigned to one of three versions of the focal question: "Who has behaviors and lifestyles that…" (1) harm the environment the most, (2) pollute the environment the most, or (3) contribute to global warming the most. Responses were coded on a 5-point scale (1 = [name of prototypical poor individual, randomized

between-subjects] harms much more the environment/ pollutes much more the environment/ contributes much more to global warming; 5 = [name of prototypical rich individual, randomized between-subjects] hams much more the environment/ pollutes much more the environment/ contributes much more to global warming). We also randomized the order of the response scale.

The filler questions, included to disguise the purpose of the study, were the following: "Who works out more?", "who watches television more?", "how much does each of them help those in need?", and "Assuming both are employed, who works more hours per week?". All questions had a similar 5-point response scale.

After answering these questions, participants were asked to justify their responses to the focal question (i.e., ecological footprint) and the employment-related filler question. In Supplementary Materials 3.1, we provide details about the coding protocol used for this open-ended question. Finally, participants completed the same attention check and sociodemographic questionnaire used in Study 1.

5.2 Results and discussion

5.2.1 (Mis)Perceptions about footprint inequality

The mean perception of ecological footprint inequality (all three outcome measures combined: environmental harm, environmental pollution, and global warming) was around the mid-point (M = 3.13, SD = 1.11), much lower than the "strictly correct" response (i.e., 5.00 = The wealthy person harms the environment *much more*; $t(346) = -31.28$ [95% CI 3.015 to 3.250], $p < 0.001$, $d = -1.68$), and also lower than the "directionally correct" response (i.e., 4.00 = The wealthy person harms the environment *slightly more*"; $t(346) = -14.53$ [95% CI 3.015 to 3.250], $p < 0.001$, $d = -0.78$; Fig. 2).

The results remain consistent when the analyses are performed separately for each type of outcome measure and compared to the "directionally correct" response (i.e., 4.00; harms the environment: M = 2.96, $t(109) = -9.40$ [95% CI 2.745 to 3.182], $p < 0.001$, $d = -0.90$; pollutes the environment: M = 3.07, $t(120) = -9.62$ [95% CI 2.884 to 3.265], $p < 0.001$, $d = -0.88$; contributes to global warming: M = 3.35, $t(115) = -6.43$ [95% CI 3.152 to 3.555], $p < 0.001$, $d = -0.59$). Similarly, the percentage of participants indicating

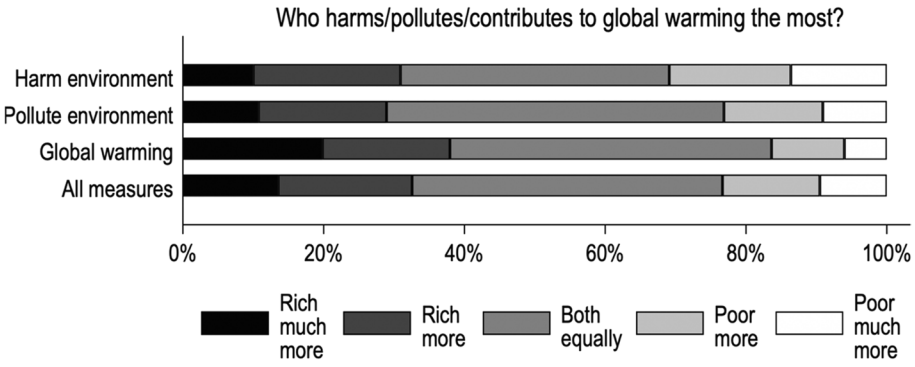


Fig. 2 Misperceptions of Ecological Footprint Inequality (Study 2). Distribution of perceptions of ecological carbon footprint across measures (environmental harm, environmental pollution, and global warming). "All measures" describes the results for the collapsed outcome variables. Raw proportions reported

that the prototypical wealthy individual harms the environment more or much more than the prototypical poor individual (i.e., scale points 4 and 5) was significantly below 50% (32.56% [95% CI 0.276 to 0.375], $p < 0.001$, standardized proportion = 0.69) irrespective of how the focal question was framed (harms the environment: 30.91% [95% CI 0.223 to 0.395], $p < 0.001$, standardized proportion = 0.67; pollutes the environment: 28.92% [95% CI 0.208 to 0.370], $p < 0.001$, standardized proportion = 0.64; contributes to global warming: 37.93% [95% CI 0.291 to 0.468] $p = 0.009$, standardized proportion = 0.78).

5.2.2 Additional analyses

Pervasiveness of the phenomenon As in Study 1, we explored the prevalence of ecological footprint misperceptions across different population subgroups, including gender, income, political ideology, race, age, and education. Our results show that the ecological footprint misperceptions were prevalent across all population subgroups (Table S6).

Underlying mechanisms Two independent coders coded the underlying reasonings for the participants' perceptions of carbon footprint inequality (interrater agreement ranged from 80% to 98%). In line with Study 1, the results showed that the correct theory (i.e., affluence → consumption → ecological footprint) was not dominant in people's minds. Only 18.73% of the participants indicated that the prototypical wealthy individual harms slightly or much more the environment because she consumes more (e.g., "Ana [the wealthy individual] probably owns a car that pollutes the air, produces more garbage, discards more clothes and is more 'consumerist'"). Though less frequently, inaccurate rationales which point to the opposite conclusion also emerged (13.26% [95% CI 0.097 to 0.168], $p = 0.059$, $d = 0.15$; e.g., "Ana [the poor individual] had less access to education/ has less access to basic sanitation.", "Maria [the poor individual] has no information about global warming.", and "Residents including Maria [the poor individual] throw garbage in the streets or anywhere else."). The belief that income had little influence on environmental impact was the rationale most frequently mentioned by participants (27.95% [95% CI 0.232 to 0.327], $p = 0.009$, $d = -0.22$; e.g., "Regardless of social or economic class, both can have good or bad habits about the environment."). Table S7 displays detailed results on the frequency of reasoning for participants' perceptions of carbon footprint inequality.

Study 2 shows that even when asked to compare the ecological footprint of prototypical individuals from the opposite poles of the economic spectrum, the apparently intuitive theory that affluence increases environmental harm through increased consumption is not highly accessible in the minds of many individuals. Further, the correct intuition is often overshadowed by competing psychological mechanisms that promote misperceptions of ecological footprint inequality. The next two studies corroborate the causal influence of these mechanisms.

6 Study 3: The role of proximal pollution

Study 3 experimentally manipulates the salience of proximal pollution. One identified reason for the misperceptions of ecological footprint inequality is the fact that poverty is often associated with proximal pollution, leading some participants to inaccurately conclude that the poor impact the environment more than the wealthy. We hypothesized that, if this is the case, making this association salient should further increase baseline misperceptions.

6.1 Method

6.1.1 Participants

Power calculations based on a pre-test using very similar stimuli suggested that a sample size of 214 participants would provide 0.95 power to detect an effect size of d = 0.45 for the mean comparison between the two experimental conditions. To maximize power and consider potential exclusions, we recruited 379 Brazilians through Netquest. Eighty-three participants failed at least one of the two attention checks. Since there was no differential attrition in the manipulation-specific attention check (χ^2 (1) = 2.61, $p = 0.106$, see below for a description), these participants were removed from analyses, as pre-registered. Our final sample included 296 respondents ($M_{Age} = 41$ years, $SD_{Age} = 13.45$; 60% male).

6.1.2 Procedure

The sample size, hypotheses, and analysis plan were pre-registered at AsPredicted (https://aspredicted.org/9HR_728). Participants were randomly assigned to one of two experimental conditions (control vs. salient proximal pollution), where they read about two hypothetical individuals, a prototypically poor and a prototypically wealthy one.

As in Study 2, participants read brief texts about two hypothetical individuals. Next, they were randomly assigned to the control or the salient proximal pollution condition. In the control condition, the descriptions contained information about the individuals' income, education, and their neighborhood of residence only (as in Study 2). In the salient proximal pollution condition, in addition to those intrinsic class aspects, the descriptions were more detailed, and emphasized cues of proximal pollution that are typical of the areas where each of the individuals lived ("dense and degraded dwellings" and "lack of basic service" in the deprived neighborhood vs. "low-density and tidy" and "wide and paved streets" in the wealthy neighborhood):

> Prototypical poor individual: *"Maria/Ana is 40 years old, earns one minimum wage, and did not complete high school. She was born and still lives in Complexo de Favelas da Maré, a highly dense and disordered conglomerate of 16 slums in the North of Rio de Janeiro. Like many favelas in other big Brazilian cities, residents of Complexo de Favelas da Maré live in degraded dwellings. There is a lack of basic public services in the neighborhood, such as proper garbage collection and water/sewage treatment. There is also a lack of malls, parking lots, and wide and paved streets."*
> *Prototypical wealthy individual: "Ana/Maria is 38 years old, earns more than 20 minimum wages, and has graduated from college. She was born and still lives in Leblon, a low-density and tidy neighborhood at the seashore of South Rio de Janeiro. Like many of the upscale neighborhoods in other big Brazilian cities, the residents of Leblon live in proper homes. There are basic public services in the neighborhood, such as garbage collection and water/sewage treatment. There are also several malls, parking lots, and wide and paved streets."* [Freely translated from Portuguese]

The names of the prototypically poor and wealthy individuals were randomized between subjects. After reading the descriptions, participants were asked the same 5 questions as in Study 2, with the focal question placed in the middle. Because the three versions of the focal question yielded similar results in the previous studies (i.e., the baseline misperceptions

were prevalent across all dependent variables), Study 3 relied on the "environmental harm" measure only. Specifically, participants were asked to indicate "who has behaviors and lifestyles that harm the environment the most (1 = [name of prototypical poor individual] hams much more the environment; 5 = [name of prototypical rich individual] hams much more the environment."

After answering the 5 questions, participants were asked to justify their responses to the focal question and the television-related filler question using an open-ended field. In Supplementary Materials 4.1, we provide details about the coding protocol used for this open-ended question. Next, they answered a manipulation-specific attention check, which was implemented to ensure that participants paid attention to our experimental conditions (see Supplementary Materials 4.2 for a detailed description of the implementation of the manipulation-specific attention check) and completed the same attention check and sociodemographic questionnaire as those used in Study 1.

6.2 Results

6.2.1 (Mis)Perceptions about footprint inequality and the role of proximal pollution

One-sample t-tests conducted in the control condition revealed that the average perception of ecological footprint inequality was much lower than both the "strictly correct" (i.e., accurate response, scale point = 5.00, "the rich individual harms the environment much more;" M = 3.31, $t(152) = 18.23$ [95% CI 3.124 to 3.491], $p < 0.001$, $d = -1.46$) and the "directionally correct" responses (i.e., response aligned to the correct direction, scale point = 4.00; $t(152) = 7.46$ [95% CI 3.124 to 3.491], $p < 0.001$, $d = -0.60$). Again, the percentage of participants indicating that the prototypical wealthy individual harms the environment more or much more than the prototypical poor individual was below 50% (37.91% [95% CI 0.302 to 0.456], $p = 0.003$, standardized proportion = 0.78), which suggests that most of the sample failed to correctly perceive the footprint inequality. As in Studies 1 and 2, such misperceptions were again prevalent across different population subgroups (Table S8).

We then examined the influence of the salient proximal pollution manipulation on misperceptions. Because poverty is often associated with proximal pollution, we hypothesized that making this association salient should further increase misperceptions of ecological footprint inequality. As expected, an independent samples t-test revealed that the misperceptions of ecological footprint inequality observed in the control condition became even more pronounced in the salient proximal pollution condition ($M_{Proximal} = 2.82$, $SD_{Proximal} = 1.17$ vs. $M_{Control} = 3.31$, $SD_{Control} = 1.15$; $t(294) = 3.57$ [95% CI 0.217 to 0.747], $p < 0.001$, $d = 0.41$; Fig. 3), which indicates a moderate increase in misperceptions due to the manipulation.

It is also interesting to notice that the effect is driven not by an increase in the number of participants indicating that both individuals harm the environmentally equally in the control (43.79%) vs. the proximal pollution condition (40.56%, z = 0.56 [95% CI -0.080 to 0.145], $p = 0.574$, $d = 0.06$). Instead, the main effect comes from an increase in the number of participants reporting that the poor harm the environment more or much more than the wealthy in control (18.30%) vs. the proximal pollution condition (35.66%, z = 3.37 [95% CI 0.074 to 0.373], $p = 0.001$, $d = 0.40$).

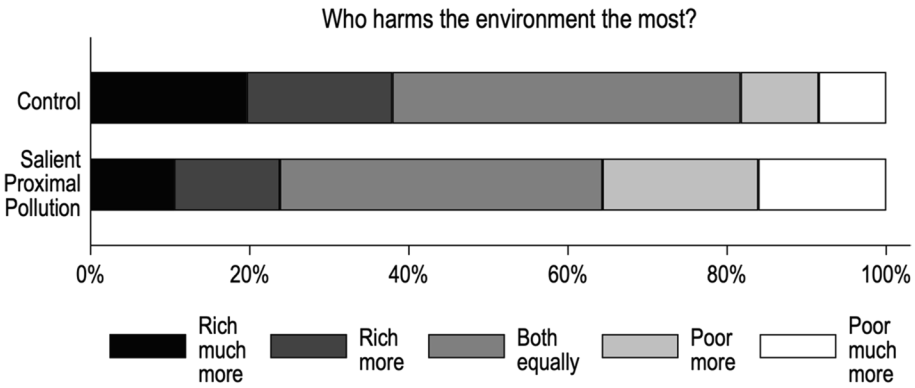


Fig. 3 Baseline Misperceptions of Footprint Inequality and the Role of Salient Proximal Pollution (Study 3). Distribution of perceptions of environmental harm across experimental conditions. Average misperceptions of environmental harm are more pronounced in the salient proximal pollution condition. Raw proportions reported

6.2.2 Additional analyses

Underlying mechanisms Further, we exploratorily analyzed the reasonings used by participants to justify their perceptions of ecological footprint inequality (Tables S9-S10). The responses were coded by two independent coders and used in a mediation model that included proximal pollution manipulation as the independent variable, proximal pollution consideration as the mediator, and perceptions of relative environmental harm as the dependent variable. Consistent with our rationale, emphasizing cues of proximal pollution increased the proportion of people using such reasoning as a justification for their responses ($\text{Proportion}_{Control} = 14.38\%$ vs. $\text{Proportion}_{Proximal} = 34.27\%$; $t(294) = 4.10$ [95% CI 0.103 to 0.294], $p < 0.001$, $d = 0.48$; Tables S9-10), which in turn enhanced the misperceptions of ecological footprint inequality ($b = -1.33$ [95% CI -1.614 to -1.058], $p < 0.001$). We observed a significant indirect effect, supporting the mediation model (indirect effect = -1.51 [95% CI -2.38 to -0.64]; Fig. S1).

Study 3 shows that nudging people to think about an inaccurate theory increases their misperceptions. The next study attempts to improve accuracy (or reduce misperceptions) by prompting participants to think about differences in consumption patterns across the socio-economic spectrum before assessing perceived differences in environmental harm.

7 Study 4: The role of consumption patterns

Study 4 examines whether making environmentally relevant class-based differences in consumption patterns salient to participants before the judgments of ecological footprint inequality increases accuracy or at least reduces the misperception. It followed the same approach used in Study 1, except that, for the sake of robustness, we asked participants to evaluate low- versus high-social class rather than low- versus high-income individuals and used a lexical option for the focal question different from the one used in Study 3 (i.e., who pollutes the environment the most?).

7.1 Method

7.1.1 Participants

Power calculations based on a pre-test using very similar stimuli suggested a sample size of approximately 168 participants to achieve 0.95 power to detect an effect size of d = 0.45 for the mean comparison between the two experimental conditions. As in Study 3, to maximize power and consider potential exclusions, we recruited 231 Brazilians through Netquest. Following the listwise deletion mentioned in the pre-registration protocol, twenty-five participants were removed from the analysis as they failed the attention check (as described in Study 1) and/or did not complete the dependent variable. Our final sample included 206 respondents (M_{age} = 45 years, SD = 14.86; 50% male).

7.1.2 Procedure

The sample size, hypotheses, and analysis plan were pre-registered at AsPredicted (https://aspredicted.org/5CP_6BS). Study 4 employed a similar procedure to Study 1. Participants were asked to evaluate their perceptions about five different social groups (e.g., "men vs. women", "younger vs. older adults") on four different behaviors (e.g., "Who watches television more?", "Who spends more time on the social media?"), with the focal question placed in the middle. The focal question was as follows: "Which of these groups has behaviors and lifestyles that pollute the environment more?" (1 = lower-class individuals pollute the environment much more, 5 = higher-class individuals pollute the environment much more) [Freely translated from Portuguese].

While the filler social groups were the same as the ones used in Study 1 (gender, age, marital status, being a parent), the focal dimension was now labeled as social class. Specifically, instead of asking participants to compare lower-income with higher-income individuals, as we did in Study 1, Study 4 asked participants to compare lower-class with higher-class individuals. Group presentation order was randomized between subjects and the dimension of interest (social class) was always presented halfway through the questionnaire.

Critically, participants were randomly assigned to one of two experimental conditions: control or salient consumption. The first two filler questions were manipulated to make salient (vs. control) the differences in environmentally relevant consumption patterns across the social groups. In the control condition, participants were asked the same four filler questions as those employed in Study 1, which have no meaningful environmental consequences: (i) "Who works out more?" (ii) "who watches more television?" (iii) "who spends more time with the family?", and (iv) "who spends more time on the social media?". In the salient consumption condition, however, the two filler questions that preceded our focal question were designed to remind participants of the differences in consumption patterns likely to have meaningful environmental consequences: (i) "Who uses a private car more than public transport?", and (ii) "who saves more electricity?". By making consumption features salient to participants (and possibly providing participants with the most accurate rationale of affluence → consumption → carbon footprint), we hypothesized that participants would improve their accuracy in the task.

As in previous studies, after answering all these questions, participants were asked to justify their responses to the focal question along with the employment-related filler question. See Supplementary Materials 5.1 for details about the coding protocol used for

this open-ended question. Finally, participants were presented with the same attention check and sociodemographic questionnaire as the previous studies (see Study 1 for a detailed description).

7.2 Results

7.2.1 (Mis)Perceptions about footprint inequality and the salience of consumption patterns

As in the previous studies, a one-sample t-test revealed that, in the control condition, the average perception of ecological footprint inequality was significantly lower than both the "strictly correct" (i.e., 5.00 = "high social-class individuals pollute the environment much more;" M = 3.06, SD = 1.14, $t(98) = 16.91$ [95% CI 2.834 to 3.284], $p < 0.001$, $d = -1.70$) and the "directionally correct" responses (i.e., 4.00 = "high social-class individuals pollute the environment slightly more;" $t(98) = 8.19$ [95% CI 2.834 to 3.284], $p < 0.001$, $d = -0.82$). Also, the percentage of participants indicating that the high social-class individuals pollute the environment more or much more than low social-class individuals was below 50% (25.74% [95% CI 0.172 to 0.343], $p < 0.001$, standardized proportion = 0.59). As in the previous studies, such misperceptions were again prevalent across different population subgroups (Table S11).

We then examined the influence of the salient consumption intervention. An assumption check revealed that, compared to the scale midpoint (i.e., "both equally"), participants indeed associate wealth (vs. poverty) with greater use of a private car versus public transportation ($M_{Car} = 4.53$ [95% CI 4.378 to 4.687], $p < 0.001$) and much lower electricity savings ($M_{Electric\ Savings} = 1.56$ [95% CI 1.407 to 1.715], $p < 0.001$). Critically, the misperceptions observed in the control condition were significantly attenuated when participants were prompted to consider these differences in environmentally relevant consumption patterns before providing their ecological footprint assessment ($M_{Control} = 3.06$, $SD_{Control} = 1.14$, $M_{Salient\ Consumption} = 3.47$, $SD_{Salient\ Consumption} = 1.37$; $t(204) = 2.31$ [95% CI 0.063 to 0..753], $p = 0.022$, $d = 0.32$; Fig. 4). Finally, the

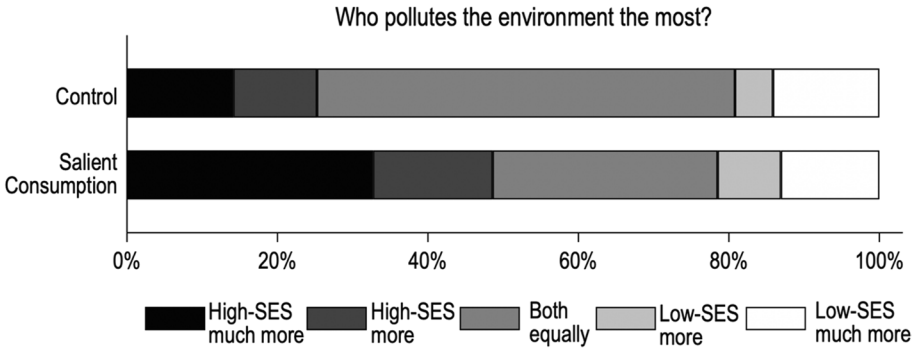


Fig. 4 Perceptions of Footprint Inequality and the Role of Differences in Consumption Lifestyle (Study 4). Distribution of perceptions of environmental pollution across experimental conditions. Average misperceptions of environmental harm are more pronounced in the salient proximal pollution condition. Raw proportions reported

percentage of participants indicating that the high social-class individuals pollute the environment more or much more than low social-class individuals in the salient consumption condition was around 50% (48.6% [95% CI 0.391 to 0.581], $p = 0.772$, standardized proportion = 0.97).

7.2.2 Additional analyses

An exploratory analysis of the participants' explanations corroborates our theorizing. When justifying their perceptions of ecological footprint inequality, participants in the salient consumption condition relied more often on the correct affluence-consumption account than those in the control condition (interrater agreement = 92.72%; $\text{Proportion}_{Control} = 14.14\%$ vs. $\text{Proportion}_{Salient\ Consumption} = 24.30\%$; $t(204) = -1.85$ [95% CI -0.210 to 0.007], p = 0.066, $d = 0.26$; see Supplementary Materials 5.3 and Tables S12-13), which in turn improved the accuracy in perceptions of ecological footprint ($b = 1.64$, [95% CI 1.266 to 2.030], $p < 0.001$). In line with the mediation model, the manipulation had a marginally positive indirect effect on perceptions of environmental pollution via consumption considerations (indirect effect = 0.16 [95% CI -0.11 to 0.36], $p = 0.07$; see Fig. S2).

8 General discussion

Although the wealthy display a much larger ecological footprint than their less privileged counterparts (Hubacek et al. 2017; Oswald et al. 2020; Wahba 2021; Wiedenhofer et al. 2017), no research to date has examined whether the layperson is aware of this fact. By addressing this gap, the current research shows that many people often fail to intuitively perceive the large ecological footprint inequality that surrounds them. Weak mental associations between differences in consumption patterns and ecological footprint, and strong mental associations between affluence and education, resources, and cleanliness help explain these misperceptions.

These findings are important because those at the bottom of the income distribution are not only the ones who contribute the least to the climate crisis (Anguelovski et al. 2019; Chancel 2022; Leichenko and O'Brien 2008), but also those who suffer the most from the climate consequences (Ciplet et al. 2015; Leichenko and O'Brien 2008; Maantay and Maroko 2009; Schuldt and Pearson 2023). Arguably, a precondition for addressing this issue is for the general population to *perceive* the massive ecological footprint inequality, which, as we demonstrate, is not necessarily the case.

8.1 Policy implications

Our results show that more accurate ecological footprint perceptions may be achieved by changing the way people from different socioeconomic backgrounds are portrayed. For example, it is not uncommon to see on the media the living environments of low-income individuals characterized by multiple cues of proximal pollution (e.g., dirt, density, disorder) and the equivalent environments of the wealthy portrayed as tidy (e.g., with wide and paved streets, big houses with plants). These prototypical characterizations may enhance viewers' misperceptions of ecological footprint inequality. Thus, a potentially successful (and cost-effective) strategy to minimize such misperceptions is to reduce the

salience of "proximal pollution" cues often attached to those more disadvantaged. Another avenue is to highlight the "stealth footprint" inherent to the consumption lifestyle of the wealthy.

Another, and even more straightforward (although more costly) strategy, is sheer education about the theme. Although academia and the press have frequently reported the vast ecological footprint inequality that surrounds us (Chancel 2022; Harvey 2022), some populations are likely much more exposed than others. Brazil ranks relatively low in "environmental performance" (81st out of the 180 countries assessed). Assuming this index represents a reasonable proxy for environmental education, exposure, and concern (Wolf et al. 2022), our sampled participants may have been particularly prone to misperceptions in ecological footprint inequality simply because many lack the knowledge needed to confront their intuitions. With that in mind, we conducted a follow-up study (N = 610) to explore the misperceptions in the US, a country with a much higher rank on the environmental performance index (43rd) —although still low compared to other OECD countries. Only 11.8% of the participants indicated that the wealthy harm/pollute/contribute to global warming much more than the poor, whereas the directionally correct response reached 46.5%. The directional accuracy is higher among the American participants compared to the Brazilian counterparts, but many still have the wrong perceptions (Supplementary Materials 6). It is plausible that for countries at the top of the environmental performance index (e.g., Denmark), accuracy may further improve.

This research can also help climate movements and policymakers inform the population and develop effective strategies to address climate change. A recent estimate indicates that by 2030 the per capita consumption emissions of the world's richest 1% will be around 30% higher than the level needed to attain the 1.5 °C Paris Agreement threshold, whereas those of the bottom 50% are expected to remain well below the required level (Bruckner et al. 2022). Poverty alleviation can be achieved with a relatively small increase in global carbon emissions, which could be fairly compensated by a reduction in the disproportionate emissions generated by the wealthy (Bruckner et al. 2022). We should all be made aware of it, after all, as this research documents, sheer intuition based on often misleading associations may direct us to inaccurate conclusions.

8.2 Limitations and future research

This research also has limitations that offer fruitful avenues for future investigation. One could argue that our results can be explained by motivated reasoning (Druckman and McGrath 2019), that is, a relatively wealthy sample of participants being unwilling to acknowledge that their social group contributes the most to environmental harm. Three reasons suggest that this alternative mechanism is unlikely. First, the portrayed wealthy individuals in Studies 2 and 3 are much wealthier than our respondents. Second, from a theoretical perspective, one could well predict the opposite effect: due to political correctness (Morris 2001), people could be reluctant to mention that lower-income individuals have a greater ecological footprint than the wealthy, even when they believe so. Third, we found no consistent associations between misperceptions of ecological footprint inequality and income, warding off any income-based concerns about our results.

A more intriguing possibility relates to the geographic characteristics of the populations. Although most of the world's population lives in urban areas (Buchholz 2020), there is still a significant proportion of the population living in relatively isolated rural settings, where proximal pollution cues are not as salient, the surroundings are greener, and the perceived

impact of consumption on the environment is minimal. All these cues could help reduce the misperception of ecological footprint inequality.

Along the same lines, our studies focus on the perceived environmental impact of the individual. However, the same reasoning could be extended to broader units of analysis (e.g., cities, countries). For example, *ceteris paribus* a wealthy nation is likely to contribute much more to global carbon emissions than a poor nation (Chancel 2022; Hubacek et al. 2017). Despite the high level of industrialization and consumption of natural resources, our findings suggest that people may underestimate the impact of the rich country's much higher per capita consumption on the environment. They may also view the poor country as a place with less educated citizens, who often live surrounded by proximal pollution, and have fewer resources to act sustainably. These mental associations may thus promote misperceptions of ecological footprint inequality. Future research may want to investigate this possibility.

As already pointed out, the most obvious way to correct these misperceptions is to educate people about the phenomenon. Thus, future research could focus on how people react once they are informed about their inaccurate assessments. Previous work has shown that providing information about the extent to which one deviates from normative behavior can under the right circumstances promote the desired behavior (e.g., energy conservation; Schultz et al. 2007). However, psychological defense mechanisms often lead people to avoid, neglect, or distort information that threatens their beliefs and identities (Ahluwalia 2000). Investigating how people respond to factual information about ecological footprint inequality and what to do to persuade them in case psychological barriers arise is imperative.

Further, this research relies on the extremes of income distribution to investigate misperceptions of ecological footprint inequality. This practice has been broadly adopted in the examination of income differences across a variety of domains (Jacob et al. 2022; Vieites et al. 2022) and is particularly justifiable in the study of footprint inequalities because objective differences in ecological footprint are more pronounced at the extremes of the distribution. This context, thus, may be interpreted as a conservative test for the documented misperceptions because high- and low-income individuals have markedly distinct levels of environmental harm and, therefore, such differences should be more easily noticeable than comparisons with middle-income individuals. Notwithstanding, those in the middle of the socioeconomic ladder represent a non-negligible portion of the population and have a meaningful impact on the environment. Indeed the 40% in the middle of the income distribution account for 43% of the global carbon emissions, nearly as much as the wealthiest 10% (47%) and much more than the poorest 50% (10%; Bruckner et al. 2022). Future research could systematically investigate perceptions of environmental harm concerning this segment of the population. Answering this question would help understand the magnitude of misperceptions across the different income groups.

Finally, previous research has extensively studied how different forms of inequality shape objective ecological footprint (e.g., gender and region; Kazemzadeh et al. 2022; Koengkan and Fuinhas 2021). Because social groups may have disparate lifestyles and patterns of consumption, they sometimes display distinct levels of environmental impact. Future studies can extend our findings by investigating whether ecological footprint misperceptions are circumscribed to income or if they apply to other social groups as well.

9 Conclusion

In this paper, we document that while higher-income individuals have a much larger ecological footprint than their lower-income counterparts, the layperson often fails to notice it. We contribute to the psychological science research agenda on climate change by documenting the important phenomenon of misperceptions of carbon footprint inequality. Further, we show that such misperceptions arise mainly due to peoples' failure to incorporate class differences in consumption patterns, and their tendency to associate poverty with lower levels of environmental education, resources to act sustainably, and lack of cleanliness in their surroundings. We thus propose policy implications to increase people's awareness of the misperceptions of carbon footprint inequality.

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Author contributions All authors designed the studies. Yan Vieites, Eduardo B. Andrade and Bernardo Andretti conceptualized the studies. Bernardo Andretti, Guilherme A. Ramos, Larissa Elmor collected the data. Bernardo Andretti and Guilherme A. Ramos analysed the data. Bernardo Andretti was responsible for data visualisation and outputs. Bernardo Andretti, Yan Vieites, Eduardo B. Andrade, and Guilherme A. Ramos drafted the manuscript. Larissa Elmor revised the manuscript and the data analysis. All authors read and approved the final manuscript.

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Data availability All studies were approved by the Institutional Review Board at Fundação Getulio Vargas IBR (reference number: CEPH/FGV 221/2021). All data and codes used in the studies are available in OSF: https://osf.io/8g436/?view_only=fb5e41269d8f422d82d56ccaed7cf7c5.

Declarations

Conflict of interest None.

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