Article

Not peer-reviewed version

Questions and Answers in the Negative Footprint Illusion Paradigm: A Reply to Gorissen et al. (2024)

Patrik Sörqvist * and John E. Marsh

Posted Date: 8 April 2024

doi: 10.20944/preprints202404.0560.v1

Keywords: negative footprint illusion; judgment; environmental impact; bias; attribute substitution

Article

Questions and Answers in the Negative Footprint Illusion Paradigm: A Reply to Gorissen et al. (2024)

Patrik Sörqvist [1,2,*] and John E. Marsh [2,3]

[1] Department of Building Engineering, Energy Systems, and Sustainability Science, University of Gävle, Gävle, Sweden
[2] Department of Health, Learning and Technology, Luleå University of Technology, Luleå, Sweden
[3] Human Factors Group, School of Psychology and Humanities, University of Central Lancashire, Preston, UK
* Correspondence: patrik.sorqvist@hig.se

Abstract: When asked to estimate the *carbon footprint* of a bundle of relatively low carbon footprint items and relatively high carbon footprint items, people typically report a lower value compared to estimating the high carbon footprint items alone. This finding is called the *negative footprint illusion* and suggests people report the average rather than sum of the combined items' carbon footprint. In a recent paper by Gorissen et al. (2024), the authors claimed that people are immune to this illusion if the question is framed differently. Specifically, they found that estimates of the *environmental friendliness* of a set comprising a burger (high carbon footprint) and an organic apple (low carbon footprint) was higher than for a set comprising the burger alone, whereas no difference was found between the two sets when participants were asked to estimate how *environmentally damaging* they were. Using larger item categories wherein the degree of the items' environmental impact is clearly communicated, here we show it does not matter whether participants are required to estimate how *friendly* or *damaging* the items are. The roles of attribute substitution, dependent variables, and independent variables (stimulus characteristics) in modulating the negative footprint illusion is discussed.

Keywords: negative footprint illusion; judgment; environmental impact; bias; attribute substitution

Introduction

When asked to estimate the *carbon footprint* of a bundle of relatively low carbon footprint and relatively high carbon footprint items, people typically report a lower value than when estimating the high carbon footprint items alone. This finding is called the *negative footprint illusion* (Gorissen & Weijters, 2016) and has been studied extensively during the last decade (see Sörqvist, Colding, & Marsh, 2020, and Andersson et al., 2024 for reviews).

One key finding is that the magnitude of the negative footprint illusion (and thus the mechanism(s) that produce the effect) depends on the characteristics of the to-be-estimated stimuli. For example, when the to-be-estimated items are distributed irregularly over the visual field, the effect increases in magnitude, in comparison with when the high carbon footprint items are presented in one group, spatially separated from another group comprising the low carbon footprint items (Sörqvist et al., 2022). Moreover, the effect is larger for a set comprising many, as compared with few, low carbon footprint items, regardless of whether the number of high carbon footprint items in the set is constant: As the number of low carbon footprint items increases, the negative footprint illusion increases even if the ratio between the number of low and high carbon footprint items remains identical (Andersson et al., 2024). The type of item also seems to matter to some extent. When an organic apple (a low carbon footprint item) is added to a burger (a high carbon footprint item) and people are asked to estimate the carbon footprint of the full meal comprising both items, the negative footprint illusion arises (Gorissen & Weijters, 2016). The same thing happens when representations of green buildings (low carbon footprint items) are combined with conventional buildings (high

 doi:10.20944/preprints202404.0560.v1

carbon footprint items) into a common set (Andersson et al., 2024; Holmgren, Andersson et al., 2018; Holmgren, Kabanshi et al., 2018; Sörqvist et al., 2022; Sörqvist & Holmgren, 2022; Threadgold et al., 2021); when hybrid cars are combined with petrol cars (Holmgren et al., 2021; Threadgold et al., 2021); but not when organic apples are combined with regular apples (Threadgold et al., 2021).

Another general tendency emerging from the growing body of literature on the negative footprint illusion is that it appears to be resistant to variations in the dependent measure. The effect seems to behave the same way regardless of whether estimates are made of the items' carbon footprint or the items' carbon dioxide emissions (Holmgren et al., 2021). Further, the effect behaves similarly when participants are asked to make an indirect estimate of the carbon footprint of the items, by estimating how many trees would be needed to compensate for the emissions associated with the construction of buildings, through the process of carbon binding (Holmgren, Kabanshi, et al., 2018). The effect seems also to be insensitive to the color of the response scale (Gorissen & Weijters, 2016). Moreover, most studies on the negative footprint illusion have used a type of response scale that may promote a qualitative rather than a quantitative mindset when making the estimates. Even so, when participants are asked to make the estimate on a quantitative/objective response scale (reporting a kilogram estimate to the question "how many kilograms CO_2 do the items generate?"), rather than a more qualitative/subjective response scale (reporting a small-large estimate to the question "how large is the item's carbon footprint?"), the negative footprint illusion still emerges (Sörqvist & Holmgren, 2022; see Biernat et al., 1991, for an influential paper on the importance of the difference between subjective and objective response scales in human judgment).

Against this background, the results from a recent study by Gorissen et al. (2024) are at first glance surprising. They found that estimates of the *environmental friendliness* of a set comprising a burger (high carbon footprint) and an organic apple (low carbon footprint) were higher than for a set comprising the burger alone, whereas no difference was found between the two sets when participants were asked to estimate how *environmentally damaging* they were. The authors argued that these results suggest an important difference between "green" and "gray" judgment scales. Green scales refer to estimates of how good something is for the environment, whereas gray scales refer to estimates of how bad something is for the environment. The authors argued that the difference arises because green scales trigger an evaluative mindset, whereas gray scales evoke a summative mindset (cf. Holmgren et al., 2018). Thus, the idea is that a negative footprint illusion, here represented by the difference in estimates of the two sets (organic apple and burger vs. burger alone), appears with the green scale, but not with the gray scale, because the green but not gray scale supposedly triggers an evaluate mindset.

In view of past research on this phenomenon, several issues arise from this line of thought. First, there is a conceptual problem. It could be argued that a dish comprising a burger and an organic apple is indeed more *environmentally friendly* than the burger alone, because the organic apple is perceived as an environmentally friendly object. Assigning a higher estimate for this set is thus true, even if the industrial production of an organic apple has a carbon footprint. This is different from the typical negative footprint illusion paradigm, wherein estimates are made of carbon footprint: A low carbon footprint house, in combination with a high carbon footprint house, does not have a lower carbon footprint in total than the high carbon footprint house alone. Assigning a lower *carbon footprint* for the combined set is therefore false. It can only become true through an attribute substitution process (Kahneman & Frederick, 2001), whereby participants (subconsciously) replace the question with the simpler one of evaluating the environmental friendliness of the items instead of the items' carbon footprint. In other words, to say that a low carbon footprint house and a high carbon footprint house in combination are more *environmentally friendly* than the high carbon footprint house alone can indeed be correct, if the houses are evaluated on this friendly-unfriendly dimension, but to say that the combination has a lower *carbon footprint* would be false.

Second, as the authors accurately point out (Gorissen et al., 2024), past studies on the negative footprint illusion have all used a gray scale, whereby the participants have been asked to evaluate how environmentally damaging the items are (in terms of, e.g., the items' carbon footprint or how much CO_2 they generate). However, a difference between the two sets (organic apple and burger vs.

 doi:10.20944/preprints202404.0560.v1

burger alone) was not found in Gorissen et al.'s study using the gray scale. Given the broad array of experiments that have incorporated gray scales and have indeed observed a negative footprint illusion with such sets, why did Gorrissen et al. fail to observe a negative footprint illusion? We believe the answer to this question lies in the stimuli they adopt.

A small set size produces a small negative footprint illusion. Sometimes small set sizes result in no negative footprint illusion at all, but rather a "zero footprint illusion" (or a quantity insensitivity effect; Kim & Schuldt, 2018) whereby estimates for a small set comprising low and high carbon footprint items are no different from those of a small set comprising just the high carbon footprint items (Andersson et al., 2024). Estimates of similar magnitude for the two sets does not reflect a negative footprint illusion but parity of estimates is not normatively correct either. Such findings might reflect a weak effect from small experimental manipulations. When comparing estimates of a single-item set with a two-item set, as in Gorissen et al.'s (2024) study, a very small negative footprint illusion is thus expected. Consistently, the difference in the *environmental damage* estimates of the two sets was in the same direction as would be expected for a negative footprint illusion (i.e., a lower *environmental damage* estimate for the burger and apple combined as compared with the burger alone), but the difference was very small and not statistically significant. A larger set size might hence paint a different picture.

Furthermore, the identity of the items appears to influence the magnitude of the negative footprint illusion. Perhaps most relevant here, is the finding that the addition of organic apples to regular apples does not produce a negative footprint illusion (Threadgold et al., 2021). Let us assume that people evaluate objects on a subjective scale ranging from very good to very bad for the environment, with the middle representing a neutral standpoint. One possibility is that apples (and presumably other natural objects) are univocally evaluated as good for the environment and thus never associated with an evaluation towards the other side of the midpoint. Thus, when you combine environmentally good things (organic apples) with other environmentally good things (apples) and ask participants how environmentally damaging these items are in combination, they do not assign a higher value to the combination of the two because neither part of the set is associated with something environmentally damaging. Asking participants to estimate how environmentally friendly that combination of organic apples and apples are, on the other hand, would probably result in a higher estimate for the combination, simply because there are more items that are perceived as environmentally friendly. Similarly, the difference in estimates concerning how environmentally damaging a set comprising an organic apple and a burger is, compared to the burger alone, is expected to be small or nonexistent. This is because a thing perceived as environmentally good is added to a thing that is perceived as environmentally bad. Therefore, the failure to find a difference between the burger and organic combination and the burger alone occurs due to the inherent characteristics of the stimulus, not because the participants' mindset has been shifted from evaluate to summative. On this logic the pattern of results might be different if stimuli are chosen that are naturally associated with values across the full range of the subjective good-to-bad scale.

The purpose of this study was to critically test whether it matters to ask participants to estimate how *environmentally damaging* versus how *environmentally friendly* a set of items is, through using a comparably large stimulus set with items that vary across the full range from good to bad. Specifically, in this study participants viewed sets comprising a couple of dozen (sketched) houses, for which their degree of environmental friendliness varied. This variation was communicated by the colour of the houses whereby green indicated a low carbon footprint (environmentally friendly), red illustrated a high carbon footprint (environmentally harmful), and yellow depicted an intermediate carbon footprint (environmentally neutral).

Methods

Participants

An a priori power analysis (using G*Power; Faul, Erdfelder, Lang, & Buchner, 2007) based on the effect size of Cohen's d_z = 0.53 for the negative footprint illusion reported in Sörqvist and Holmgren (2022) revealed that 49 participants would be enough to detect the effect in a within-

 doi:10.20944/preprints202404.0560.v1

participants design with power (1 – β error probability) set to 0.95 and assuming a two-tailed hypothesis. A total of 59 individuals took part in this study (70 % women, 29 % men, and 1 % who either did not want to reveal their gender or identified with another gender). Thus, the study was adequately powered. The participants' mean age was 26.04 years (*SD* = 7.20). They all participated under informed consent and received a small honorarium for their participation.

Materials

Sketched houses were used as stimuli and were identical except that they were depicted in either green, yellow, or red color. These houses were distributed across an invisible 9×8 matrix to create 7 pictures (see Figure 1 for examples): green-coloured houses only (24 green houses, pseudo-randomly distributed, such that each row had 3 houses), yellow-coloured only (24 yellow houses, distributed as the green houses in the matrix), red-coloured only (24 red houses, distributed as the green houses in the matrix), green and yellow houses (24 of each), red and yellow houses (24 of each), green and red houses (24 of each), and a picture with all three types of house (24 of each, thus all cells in the matrix were filled). These 7 pictures were also all inverted over the x-axis, to create another set of 7 pictures with the same contents but with the houses distributed differently.

Figure 1. Examples of the stimulus material used in the experiment: only green houses (Panel A), yellow and red houses (Panel B), and a picture with all three types of houses (Panel C).

Design and Procedure

A within-participants experimental design was used. The participants sat alone, in a lab, in front of a desktop computer during the data collection. The computer controlled the presentation of instructions, stimulus material and response collection. At the onset, the participants read instructions about the environmental impact of buildings and how this environmental impact can be represented by a colour system ranging from green to red. They were also told that their task would be to view picture of houses with various environmental impact corresponding to their colour, and to make estimates of the houses combined environmental impact in two ways: either by judging how environmentally friendly the houses in the picture are, or by judging how environmentally damaging the houses in the picture are. After reading the instructions, the participants pressed a button to proceed to the estimation task. The task was divided in two blocks. In one block, the computer presented each of the 7 pictures in random order and asked participants to estimate how environmentally friendly the items are, one picture/estimate at a time. Estimates were made on a seven-point scale (similar to Gorissen et al., 2024) ranging from 1 (not environmentally friendly) to 7 (environmentally friendly). The participants were allowed as much time as they needed to make an estimate and pressed a button to proceed to the next picture. The other block was identical, with the exception that here participants were asked to estimate how environmentally damaging the items are. Estimates were made on a seven-point scale ranging from 1 (environmentally damaging) to 7 (not environmentally damaging). Note that a low number for both scales represents "bad for the

 doi:10.20944/preprints202404.0560.v1

environment" and a high value represents "good for the environment". Seven estimates (out of 826 estimates in total) were missing, probably due to omissions. These missing data points were replaced by the average of the estimates of the corresponding item set. The order of the two blocks was counterbalanced between participants, so that half began with making damaging estimates in the first block they encountered, while the other half began with making friendliness estimates in the first block they encountered. At the switch between blocks, participants read a brief instruction of the change in the judgment scale. The regular pictures were presented in the first block, and the inverted versions of the pictures were presented in the second block. The whole experiment took 5-10 minutes to complete. The data can be accessed from doi.org/10.17605/OSF.IO/SXMQC

Results

As can be seen in Figure 2, the pattern is similar across the two scales. The first thing to note is that participants assigned a lower environmental damaging estimate to an item set comprising green and yellow houses in comparison with a set comprising the yellow houses alone, $t(58) = 8.30$, $p < .001$, Cohen's d = 1.08, BF_{01} = 1,9501E-9. This corresponds to the typical pattern found in the negative footprint illusion literature, but in that literature as opposed to here, participants have been requested to estimate the carbon footprint of the items.

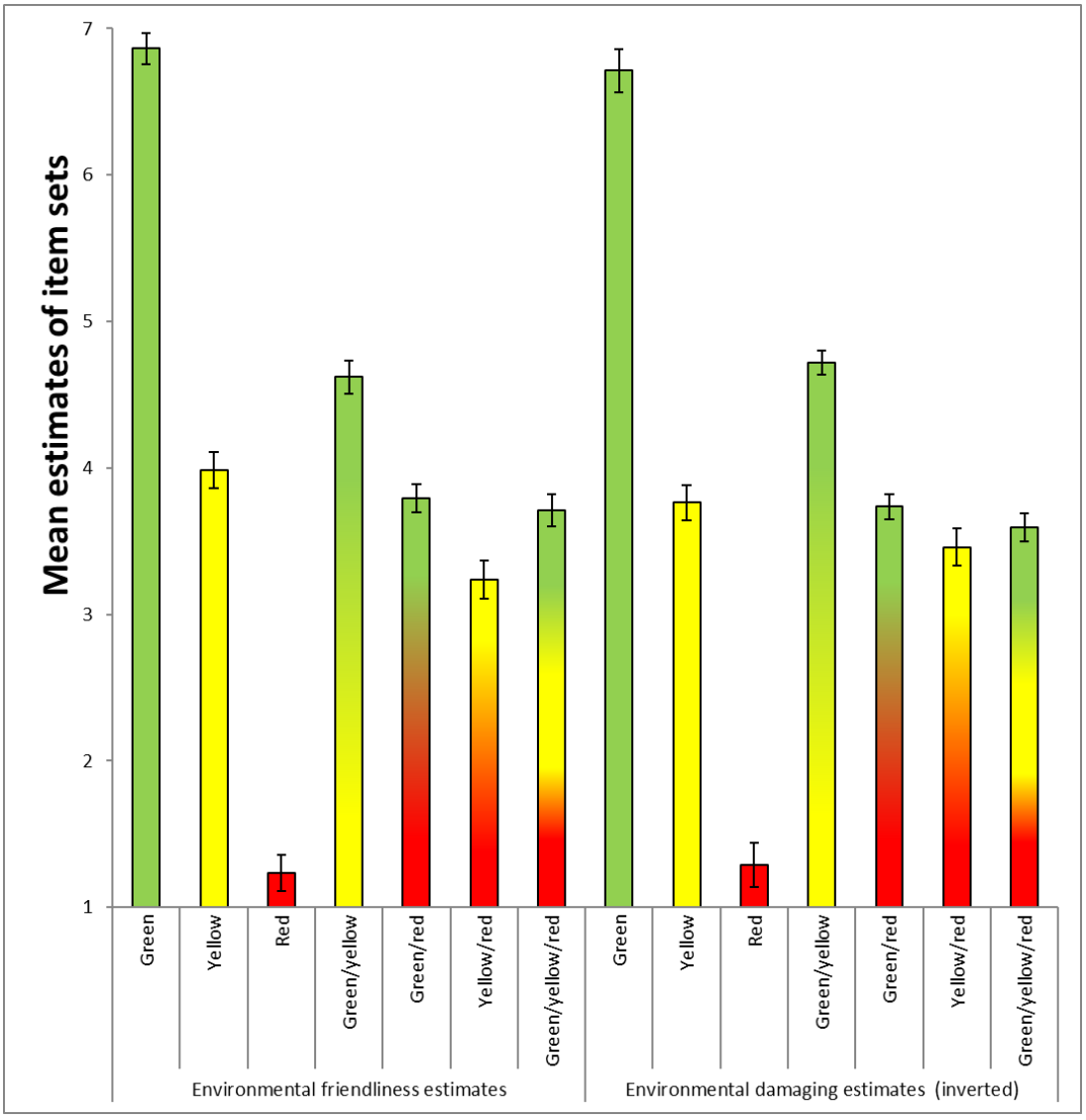

Figure 2. Mean estimates of different clusters of stimuli across two judgment scales: estimates of how environmentally friendly the items are and estimates of how environmentally damaging the items

 doi:10.20944/preprints202404.0560.v1

are. Note that higher values for the environmental friendliness estimates represent higher environmental friendliness, and higher values for the environmentally damaging estimates represent lower environmental damage as the latter scale was inverted. Error bars represent standard error of conditional means.

The second thing to note is that participants also assigned a higher environmental friendliness estimate to an item set comprising green and yellow houses in comparison with a set comprising the yellow houses alone, $t(58) = 4.13$, $p < .001$, Cohen's d = 0.54, $BF_{01} = 0.006$. This difference between the two conditions was similar in magnitude across the two scales. The mean difference scores for the estimates of a set with green + yellow houses and a set with yellow houses were 0.96 ($SD = 0.89$) for the gray scale and 0.64 ($SD = 1.18$) for the green scale, respectively. Although these means differed statistically, $t(58) = 2.05$, $p = .045$, Cohen's d = 0.24, $BF_{01} = 1.32$, the results demonstrated the difference was larger for the environmentally damaging than environmentally friendliness ratings. However, the Bayesian analysis favors the null over the hypothesis. Thus, the empirical marker that corresponds to a negative footprint illusion was similar across the green and gray judgment scales. That the difference was, if anything, larger for the environmental damaging estimates contradicts the findings of Gorissen et al. (2024).

Discussion

The experiment reported here revealed estimation patterns very similar for estimates of items' *environmental friendliness* and estimates of how *environmentally damaging* the items are. The reason for the differences between the results reported here and the results reported in Gorissen et al. (2024) can presumably be attributed to differences in the stimulus sets. With large enough sets with stimuli spanning the full range of the environmentally good-bad scale, the results for the two judgment scales become nearly identical.

There is a clear resemblance between the pattern of results obtained with the two judgment scales used here and the judgments of carbon footprint used in the typical negative footprint illusion paradigm (e.g., Gorissen & Weijters, 2016; Holmgren, Andersson et al., 2018). This suggests that a driving force behind the negative footprint illusion is indeed attribute substitution (Kahneman & Frederick, 2001), whereby participants replace the more difficult question that requires them to assign a carbon footprint value to the objects with the easier question that requires them to evaluate the object on a good vs. bad continuum and assign a value based on that instead (cf. Holmgren, Kabanshi et al., 2018). This assumption also coheres with the idea that many judgments under uncertainty are guided by an affect heuristic (Slovic et al., 2007)—the tendency to base judgments on the perceived positive ("goodness") or negative ("badness") qualities of a stimulus instead of their quantitative properties, often at the expense of more analytical information processing (cf. Evans & Stanovich, 2013a, 2013b).

Attribute substation could explain why the negative footprint illusion seems to be driven by an averaging bias (Holmgren et al., 2018). For example, if the task is to estimate the carbon footprint of a set comprising high and low carbon footprint houses, but the participants replace the task with estimating how environmentally bad the items are instead, then assigning a lower value to the combined set of low and high carbon footprint houses in comparison with the high carbon footprint houses alone becomes a true response. When participants adopt this interpretation, they can be thought of as providing a normative response to a problem that is different to what was intended in the study (Toplak, 2021). Indeed, the averaging bias can also explain related phenomena seen in studies on environmental impact estimates such as the quantity insensitivity effect (Kim & Schuldt, 2018; Kusch & Fiebelkorn, 2019). For example, environmental impact estimates of a set comprising two low carbon footprint items (two hybrid cars) are no different from estimates of one low carbon footprint item (one hybrid car) (Kim & Schuldt, 2018). This quantity insensitivity effect can be perfectly explained by the averaging bias account, as the average of two identical items is the same as the average of one item alone.

 doi:10.20944/preprints202404.0560.v1

Yet, attribute substitution (and the averaging bias) seems not to offer a full explanation of the mechanisms driving the negative footprint illusion. For instance, attribute substitution by itself can hardly explain why stimulus distribution across the visual field influences the magnitude of the effect (Sörqvist et al., 2022). An irregular stimulus distribution of the low carbon footprint items might increase the perceived environmental friendliness of the items, but it is unclear why the irregular distribution of the high carbon footprint items—following the same line of thought—does not compensate for this by increasing the perceived environmental unfriendliness of these items. Likewise, attribute substitution cannot explain why larger sets receive smaller carbon footprint estimates than smaller sets, even when the ratio between high carbon footprint and low carbon footprint items in the sets are held constant (Andersson et al., 2024). Larger sets of low carbon footprint items could increase the perceived environmental friendliness of the set, thereby leading to a lower carbon footprint estimate for these sets, but it is unclear why this would not be contradicted by the corresponding increase in the number of high carbon footprint items. One possibility is that there is a positivity bias involved, wherein more weight is assigned to the environmentally friendly than to the environmentally unfriendly items during the judgment formation process. When an irregular distribution makes the stimulus sets become perceived as larger, or when objects in the stimulus sets increase in number, this could interact with a positivity bias to produce a larger negative footprint illusion. This might be worthwhile exploring in future studies.

In conclusion, attribute substitution and the conceptual problems raised in the introduction section above stress the importance of a careful consideration of whether the selected response scale measures the negative footprint illusion, or whether it measures something else. In other words, if participants are not asked to estimate the carbon footprint of the items (or at least something related to the items' carbon footprint, e.g., CO_2 emissions or the number of trees needed to compensate for emissions), but instead how environmentally friendly the items are, is the negative footprint illusion then actually studied? The negative footprint illusion appears to be relatively insensitive to the type of response scale used, but it is influenced by stimulus characteristics and their interactions with what participants are asked to evaluate. Future studies on the negative footprint illusion could explore those interactions in more detail.

References

1. Anderson, H., Holmgren, M., Sörqvist, P., Threadgold, E., Beaman, C. P., Ball, L. J., & Marsh, J. E. (2024). The negative footprint illusion is exacerbated by the numerosity of environment-friendly additions: Unveiling the underpinning mechanisms. *Journal of Cognitive Psychology*.
2. Biernat, M., Manis, M., & Nelson, T. E. (1991). Stereotypes and standards of judgment. *Journal of Personality and Social Psychology, 60,* 485-499.
3. Evans, J. S. B. T., & Stanovich, K. E. (2013a). Dual-process theories of higher cognition: advancing the debate. *Perspectives in Psychological Sciences*, *8*, 223–241.
4. Evans, J. S. B. T., & Stanovich, K. E. (2013b). Theory and metatheory in the study of dual processing: reply to comments. *Perspectives in Psychological Science*, *8*, 263–271.
5. Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavioral Research Methods, 39,* 175-191. DOI: 10.3758/bf03193146
6. Gorissen, K., & Weijters, B. (2016). The negative footprint illusion: Perceptual bias in sustainable food consumption. *Journal of Environmental Psychology, 45,* 50-65.
7. Gorissen, K., Weijters, B., & Beltomme, B. (2024). Green versus grey framing: Exploring the mechanism behind the negative footprint illusion in environmental sustainability assessments. *Sustainability, 16,* 1411.
8. Holmgren, M., Andersson, H., Ball, L. J., & Marsh, J. E. (2021). Can the negative footprint illusion be eliminated by summative priming? *Journal of Cognitive Psychology, 33*, 337-356.
9. Holmgren, M., Andersson, H., & Sörqvist, P. (2018). Averaging bias in environmental impact estimates: Evidence from the negative footprint illusion. *Journal of Environmental Psychology, 55,* 48-52.
10. Holmgren, M., Kabanshi, A., Marsh, J. E., & Sörqvist, P. (2018). When A+B < A: Cognitive bias in experts' judgment of environmental impact. *Frontiers in Psychology, 9,* Article 823, 1-6.
11. Kahneman, D., & Frederick, S. (2001). Representativeness revisited: Attribute substitution in intuitive judgment. In T. Gilovich, D. W. Griffin, & D. Kahneman (Eds.), *Heuristics and Biases: The Psychology of Intuitive judgment* (pp. 49-81). Cambridge University Press.
12. Kim, B., & Schuldt, J. P. (2018). Judging the environmental impact of green consumption:

 doi:10.20944/preprints202404.0560.v1

13. Evidence of quantity insensitivity. *Journal of Environmental Psychology, 60,* 122-127.
14. Kusch, S., & Fiebelkorn, F. (2019). Environmental impact judgments of meat, vegetarian, and insect burgers: Unifying the negative footprint illusion and quantity insensitivity. *Food Quality and Preference*, 103731, 1-10.
15. Slovic, P., Finucane, M. L., Peter, E., & MacGregor, D. G. (2007). The affect heuristic. *European Journal of Operational Research, 177,* 1333-1352.
16. Sörqvist, P., Colding, J., & Marsh, J. E. (2020). Psychological obstacles to the efficacy of environmental footprint tools. *Environmental Research Letters, 15*, 091001.
17. Sörqvist, P., & Holmgren, M. (2022). The negative footprint illusion in environmental impact estimates: Methodological considerations. *Frontiers in Psychology, 13,* 990056.
18. Sörqvist, P., Volna, I., Zhao, J., & Marsh, J. E. (2022). Irregular stimulus distribution increases the negative footprint illusion. *Scandinavian Journal of Psychology, 63,* 530-535.
19. Threadgold, E., Marsh, J. E., Holmgren, M., Andersson, H., Nelson, M., & Ball, L. J. (2021). Biased estimates of environmental impact in the negative footprint illusion: The nature of individual variation. *Frontiers in Psychology*, *12*, Article 648328, 1-16.
20. Toplak, M. E. (2022). Cognitive sophistication and the development of judgment and decision-making. Academic Press.