Averaging bias in environmental impact estimates: Evidence from the negative footprint illusion

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A B S T R A C T

In this paper we argue that unsustainable behaviors often stem from a common averaging bias when people estimate the environmental impact of a set of environmentally friendly and less friendly objects or actions. In Experiment 1, we show that people believe that the total carbon footprint of a category of items (a community of buildings in this case) is lower, rather than higher, when environmentally friendly (“green” buildings) items are added to the category, a negative footprint illusion. Experiment 2 showed that the carbon footprint estimate assigned to a category with a mix of environmentally friendly and less friendly objects (“green” and conventional buildings) is the average of its subsets (the “green” buildings and the conventional buildings, respectively), an averaging bias. A similar averaging process may underpin estimates of the environmental impact of people’s own actions, explaining why people believe that environmentally friendly actions can compensate for less friendly actions.

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1. Introduction

One of society’s grand challenges today is global climate change (American Psychological Association, 2008; Hansen et al., 2013), which partly is a consequence of anthropogenic greenhouse gas emissions (National Academy of Sciences Committee, 2001). Climate change can be mitigated by various engineering and agricultural interventions such as implementing “green” buildings (Zuo & Zhao, 2014) and increase eco-friendly produce (Gattinger et al., 2012). However, the technology necessary for a more sustainable society is already available. The barriers today appear rather to be psychological in nature (Thollander & Palm, 2013). It is therefore vital to study how climate change can be managed by the promotion of environmentally sustainable behavior (Ernst & Theimer, 2011; Kaiser, Hartig, Duvier, & Brügger, 2013), such as recycling (Chen & Tung, 2009), “green” consumption (Alfredsson, 2004), and energy conservation (Gardner & Stern, 2008), and to understand how a more sustainable built environment influences people (Sörqvist, 2016).

One psychological barrier that can prevent sustainable behavior is that pro-environmental behavior, in some cases, leads to undesirable behaviors after the pro-environmental act (e.g., Tiefenbeck, Staake, Roth, & Sachs, 2013). The vast majority of these undesirable behaviors are closely related to a phenomenon called “negative spillover”, which occurs when “one pro-environmental behavior decreases the likelihood of additional pro-environmental behaviors” (Truelove, Carrico, Weber, Raimi, & Vandenberghe, 2014, p. 128). Two types of negative spillover occurrences in the energy domain have been termed the direct and the indirect rebound effect. The former refers to when energy efficiency improvements lead the consumer to use the service more, whereas the latter refers to when the efficiency improvements result in increased demand in an unrelated behavior (Chitnis, Sorrell, Druckman, Firth, & Jackson, 2013). Increased driving distance as a result of fuel efficiency would be an example of a direct rebound effect. On the other hand, an example of an indirect rebound effect would be if money saved on fuel efficiency were later spent on a more extensive vacation, which would lead to a greater environmental impact due to, for example, air travel.

The two types of rebound effects are closely related to moral licensing, which occurs when people feel licensed to act immorally after establishing moral credentials (e.g., engaging in moral actions; Mazar & Zhong, 2010; Sachdeva, Iliev, & Medin, 2009). As acting pro-environmentally is considered by many as moral behavior (Steg, Drejerink, & Abrahamse, 2005; Stern, 2000), moral licensing has been found in the context of environmental related actions. For example, Klöckner, Nayum, and Mehmetoglu (2013) found that
electric car owners felt less obligated to behave in a pro-environmental manner compared to conventional car owners. A controlled field experiment showed that implementing a water conservation campaign correspondingly decreased water use, but increased electricity consumption compared to a control group (Tiefenbeck et al., 2013). Moreover, the occurrences of moral licensing effects are not limited to a single behavioral domain but can also occur between domains (i.e., cross-domain moral licensing). For example, people are more likely to steal and cheat after purchasing eco-friendly products compared to after purchasing conventional products (Mazar & Zhong, 2010). Similarly, a study by Norton (2012) found that hybrid car drivers violated cross walk laws more frequently compared to drivers of conventional cars. Moral licensing may occur from a surplus of a symbolic moral currency, which might be a result from acting more morally than necessary (Sachdeva et al., 2009). As pro-social behavior is costly to engage in, moral licensing becomes a tool for the agent to return to a more comfortable level, that is, a regression to the individual average of the moral currency.

Finally, rebound effects and moral licensing resemble what is called compensatory green belief. Compensatory green beliefs refer to the belief that engaging in a pro-environmental act (e.g., recycling) can compensate for engaging in an unsustainable behavior (e.g., driving a car). Endorsement of compensatory green beliefs has been shown to correlate negatively with “green” identity, pro-environmental behavior, concern with climate change, and environmental values (Kaklamanou, Jones, Webb, & Walker, 2015).

We propose that these phenomena—moral licensing, rebound effects, and compensatory green beliefs—may all be examples of a bias in people’s way of thinking about the environmental impact of a set of environmentally friendly and less environmentally friendly objects or actions. Specifically, we argue that people tend to think that the environmental impact of a mix of more or less environmentally friendly items are the average, rather than the sum, of these items. This averaging bias can, for example, be shown in the context of the negative footprint illusion: people tend to think that a meal (e.g., a hamburger) with an eco-friendly side (e.g., an eco-labeled apple) has altogether a lower carbon footprint than the meal alone, while the combination of the meal and the eco-friendly side in actuality has a higher carbon footprint than the meal alone (Gorissen & Weijters, 2016). The bias may in turn explain why people think environmentally friendly actions can compensate for less friendly actions, which underpin moral licensing, rebound effects and compensatory green beliefs.

The purpose of the present paper was to demonstrate the averaging bias in people’s environmental impact estimates. To this end, we developed a version of the negative footprint illusion paradigm that made it easy to manipulate the quantity of the estimated items (Experiment 1); and we tested whether people’s carbon footprint estimates of a set of environmentally friendly and conventional objects, in combination, is the average (rather than the sum) of their estimates of environmentally friendly objects and conventional objects respectively (Experiment 2).

2. Experiment 1

In this experiment, the participants were allocated to one of three conditions: one third was assigned to a condition where they were presented with 15 conventional houses (hereinafter referred to as the control condition); the second third was presented with 15 conventional houses to which another 5 conventional houses were added (hereinafter referred to as the conventional addition condition); and the last third was allocated to a condition where they were presented with 15 conventional houses with an addition of 5 houses described as environmentally certified (hereinafter referred to as the green addition condition). We expected to find a negative footprint illusion such that participants would report a lower carbon footprint in the green addition condition compared to the control condition, even though the community as a whole in the green addition condition — indisputably — should be assigned a higher carbon footprint compared to the community in the control condition.

3. Method — experiment 1

3.1. Participants

A total of 90 students (56% women) at the University of Gävle (mean age = 26.31 years, SD = 6.56) were recruited to participate in the study. All participants received a small honorarium for their participation.

3.2. Materials

A questionnaire was used to obtain data. On the first page of the questionnaire, all participants (in all conditions) were informed that they were about to take part in a survey regarding estimations of buildings’ carbon footprints. The meaning of the term “carbon footprint” was explained to the participants and they were additionally told that the lower the carbon footprint the less impact on the environment. On the next page of the questionnaire, one third of the participants were assigned to the control condition, the second third to the green-addition condition and the last third to the conventional addition condition. In the control condition, they were presented with a figure that presented 15 conventional houses (see Fig. 1) and were given the question: “These yellow houses represent 15 houses in a community, please estimate the combined carbon footprint (environmental impact) the houses have together”. In the green-addition condition they were presented with a figure that presented 15 conventional houses with an addition of 5 environmentally certified houses (see Fig. 1) and were given the question: “These yellow houses represent 15 houses in a community. The community has decided to build 5 additional houses, all of which will be environmentally certified. Please estimate the combined carbon footprint (environmental impact) the houses have together when the five additional environmentally certified houses have been built”. In the conventional addition condition, they were presented with a figure that presented 15 conventional houses with an addition of 5 conventional houses (see Fig. 1) and were given the question: “These yellow houses represent 15 houses in a community. The community has decided to build 5 additional houses. Please estimate the combined carbon footprint (environmental impact) the houses have together when the five additional houses have been built”. The participants made the estimations on a scale ranging from 1 (very low impact) to 9 (very high impact). They were also given a reference point, which stated: “A point of reference you can consider while making your estimate is that an apartment building with 18 apartments would have scored 5 on the scale”. The purpose of the reference point was to give, as far as possible, the participants a common understanding of the scale. The reference point was deliberately ambiguous instead of suggesting how much carbon a single house in the picture would contribute with, because we did not want the participants to solve the task by simply adding the carbon footprint value of each house together.

3.3. Design and procedure

A between-participants design was used with display of houses as the independent variable. The participants were randomly...
assigned to one of three conditions: the control condition (N = 30), the green-addition condition (N = 30), and the conventional-addition condition (N = 30). The experiment took place in a laboratory at the University at Gavle. The participants sat alone in the laboratory room during the experiment. It took the participants about 5 min to complete the task.

4. Results – experiment 1

A univariate analysis of variance across all conditions was calculated with carbon footprint estimation as the dependent variable. The analysis revealed a significant difference between conditions, F(2, 87) = 7.37, p < .001, η² = 0.15. Independent samples t-tests revealed that the participants in the green-addition condition (i.e., 15 conventional + 5 “green” houses) estimated the footprint as significantly lower than did the participants in the control condition (i.e., 15 conventional houses), t(58) = 3.05, p = .003, η² = 0.14, and lower than did the participants in the conventional addition condition (15 conventional + 5 conventional houses), t(58) = 3.24, p = .002, η² = 0.15. There was no significant difference between the control condition and the conventional addition condition, t(58) = 0.22, p = .825, η² = 0.00. As hypothesized, the participants assigned a lower carbon footprint estimate to the community in the green addition condition (M = 5.43, SD = 1.59) than to the community in the control condition (M = 6.53, SD = 1.17) and to the community in the conventional addition condition (M = 6.60, SD = 1.16) with only conventional houses.

5. Discussion – experiment 1

Experiment 1 replicated the negative footprint illusion (Gorissen & Weijters, 2016) in the context of our new version of the paradigm. Specifically, people tend to think that the environmental impact of conventional and “green” buildings, together, is lower than that of conventional buildings alone. The strength of this version of the paradigm, using quantity of buildings rather than food products, is that it is easy to manipulate the quantity of the to-be-estimated objects, which is necessary to test whether the averaging bias underpins environmental impact estimates. The absence of a difference between the control and the conventional addition condition may be a result of an insufficient contrast between the two conditions (i.e., five conventional houses).

6. Experiment 2

The purpose of Experiment 2 was to test for the averaging bias. More specifically, Experiment 2 was designed to test whether the lower carbon footprint estimates emerge as a consequence of the mere presence of “green” buildings, or through an averaging process comprised of the combined carbon footprint estimates of the conventional and the “green” buildings. If people tend to average the carbon footprint of the “green” houses with the carbon footprint of the conventional houses, then the estimated carbon footprint of a condition with 15 conventional and 15 “green” houses (hereinafter referred to as conventional and “green” houses condition) should fall between the estimates of a condition with only 15 “green” houses (hereinafter referred to as the “green” only condition) and a condition with only 15 conventional houses (hereinafter referred to as the conventional only condition). In turn, if it is the presence of “green” buildings themselves that makes people assign lower carbon footprint values (due to for example a preference bias for environmentally certifiled buildings; see Holmgren, Kabanshi, & Örqvist, 2017) without mentally constructing an average of the conventional and the “green” houses, then the two conditions with “green” houses should not differ.

7. Method – experiment 2

7.1. Participants

A total of 79 students (57% women) at the University of Gavle (mean age = 26.33 years, SD = 7.69) were recruited to participate in the study. All participants received a small honorarium for their participation. None of them participated in Experiment 1.

7.2. Materials

The questionnaires were identical to those in Experiment 1 except for the necessary changes made in view of a different number of houses displayed. The number of houses displayed in each condition corresponded to the conventional and “green” houses condition (15 + 15 houses), the “green” only condition (15 houses) and the conventional only condition (15 houses).
7.3. Design and procedure

A between-participants design was used with display of houses as the independent variable. The participants were randomly assigned to one of three conditions: the conventional only condition (N = 25), the “green” only condition (N = 24), and the conventional and “green” houses condition (N = 30). The experiment took place in a laboratory at the University at Gavle. The participants sat alone in the laboratory room during the experiment. The task took about 5 min to complete.

8. Results – experiment 2

As can be seen in Fig. 2, the participants in the conventional and “green” houses condition estimated the carbon footprint as significantly lower than did the participants in the conventional only condition. They also assigned a carbon footprint to the combination of conventional and “green” houses that was higher than the participants in the “green” only condition. A one-way analysis of variance across the three conditions was calculated with carbon footprint estimation as the dependent variable. The analysis revealed a significant difference between conditions, F(2, 76) = 14.25, p < .001, η² = 0.27. Independent samples t-tests revealed that the participants in conventional and “green” houses condition (i.e., 15 conventional + 15 “green” houses) estimated the carbon footprint as significantly lower compared to the participants in the conventional only condition (i.e., 15 conventional houses), t(53) = 2.44, p = .018, η² = 0.10. The participants in the “green” only condition (i.e., 15 “green” houses) estimated the carbon footprint as significantly lower compared to the participants in the conventional only condition, t(47) = 5.02, p < .001, η² = 0.35, as well as compared to the participants in the conventional and “green” houses condition, t(52) = 3.21, p = .002, η² = 0.17.

9. Discussion – experiment 2

Experiment 2 replicated the main finding from Experiment 1 by showing that people are biased into believing that the total carbon footprint of a community decreases when environmentally certified buildings are added. Furthermore, the key finding from Experiment 2 was that the participants seem to conduct an averaging process comprised of the perceived carbon footprint of the conventional and the “green” buildings together. Therefore, the lower carbon footprint estimates in conditions with “green” buildings are not simply a result of the presence of “green” buildings.

10. General discussion

The experiments reported in this paper revealed two main findings. First, people are biased to believe that an addition of “green” buildings (to conventional buildings) can reduce the total carbon footprint of a community. This belief runs contrary to the actual carbon footprint of the total community which increases when environmentally certified buildings are added. In other words, when people make environmental impact estimates of a category, A and B, wherein A is “conventional” items and B is “environmentally friendly” items, then they think that A + B is less than A. Second, it is not the mere presence of “green” buildings that causes this downward shift in the carbon footprint estimate. Instead, the illusion appears to be underpinned by an averaging process whereby the perceived carbon footprint of the “green” buildings together with the perceived carbon footprint of the conventional buildings is averaged. People base their carbon footprint estimate of a category of items, A and B, on the average of A and B, rather than the sum of A and B. This averaging process results in a biased carbon footprint estimate, whereas adding the values of “green” buildings to the values of the conventional buildings into an aggregated estimate would be more accurate.

The suggestion of the presence of an averaging bias is specifically supported by the finding that the estimated carbon footprint of conventional and “green” houses fall between the estimates of the “green” houses only and estimates of conventional houses only. To explore this, we returned to the data from Experiment 2 and calculated the combined average of the estimates in the “green” only condition together with the estimates made in the conventional only condition (M = 5.21). Then we ran one-sample t-tests with this average as the test-value. The estimates in the conventional only condition were higher compared to the test value, t(24) = 4.44, p < .001, whereas the estimates in the “green” only condition were lower, t(23) = -2.99, p = .007. The conventional and “green” condition did not differ from the test value, t(29) = 1.10, p = .282. These results are well in line with the averaging bias account of the negative footprint illusion.

We suggest that the averaging bias in environmental impact estimates reflects a more general cognitive bias that appears in many contexts and behavioral settings where people assess (consciously or unconsciously) a mix of objects or actions. A similar phenomenon has, for example, been found in health estimates of food products (Chernev & Gal, 2010). The averaging bias may also account for why people think that environmentally friendly actions can compensate for less environmentally friendly actions, which

![Fig. 2. Mean carbon footprint estimates assigned to the conventional and “green” buildings condition, the “green” only condition and the conventional only condition in Experiment 2. Vertical bars represent 95% confidence intervals.](image)
leads to rebound effects and moral cleansing. The problem people face when assessing the environmental impact of their own actions can be seen as a categorization problem similar to the problem the participants faced in the study reported here. When making the assessment of the environmental impact of a set of more or less environmentally friendly actions, people may end up with an average of these actions rather than the sum of the actions, which may explain why people think that more environmentally friendly actions can compensate for less environmentally friendly actions. The tendency to think in terms of averages rather than sums could perhaps, for example, make people buy more eco-friendly food in an attempt to become more environmentally friendly overall.

The negative footprint illusion conceptually resembles the conjunction fallacy studied extensively in the decision making literature (Tversky & Kahneman, 1983). For a full understanding of the negative footprint illusion, it might therefore be useful to mention the conjunction fallacy in more detail. According to the conjunction rule, the probability of a conjunction, \( P(A \& B) \), cannot exceed the probabilities of its constituents, \( P(A) \) and \( P(B) \), because the possibility of the conjunction is included in the extension of its constituents. Tversky and Kahneman showed in one of their classic experiments that people who make judgments under uncertainty are sometimes biased into believing that the probability of \( A \& B \) is larger than the probability of \( A \) alone, even though this is faulty thinking on rational grounds. In their experiments, the participants read a description of Linda and were asked to judge the likelihood of her occupation. The participants thought it was more likely that Linda was a bank teller and active in a feminist movement, \( P(A \& B) \), than a bank teller, \( P(A) \), alone. The negative footprint illusion resembles the conjunction fallacy in that people are biased into estimating the carbon footprint of a meal and an eco-friendly side dish, \( \text{CO}_2(A \& B) \), as lower than the carbon footprint of the meal alone \( \text{CO}_2(A) \) (Gorissen & Weijters, 2016). That being said, the two biases are not necessarily underpinned by the same cognitive operations or mechanisms as they concern judgments in distinct contexts, and one of them results in the assignment of a higher value to the conjunction and the other in the assignment of a lower value to the conjunction. More specifically, whereas the conjunction fallacy is triggered by a biased summative mental process, the negative footprint illusion is triggered by a biased averaging mental process.

### 10.1. Limitations of the study and directions for future research

This study is (to our knowledge) the first to show that the negative footprint illusion seems to be underpinned by an averaging bias. The study has, however, some limitations. One limitation has to do with the potential applied implications of the study. The laboratory task assigned to the participants only entailed abstract representations of two types of buildings which, for example, hardly represents the task faced by a city planner who are planning on building “green” suburbs for a more sustainable city. Future research could aim to develop a more ecologically valid task to investigate to what extent the averaging bias influence decision making in the city planning processes. Furthermore, future research should consider whether individual differences between participants modulate the responses, such as individual differences in environmental concern and the role of intuitive versus reflective processing. Moreover, the study that first demonstrated the negative footprint illusion (i.e., Gorissen & Weijters, 2016) used two types of judgmental scales, one that would stimulate a categorical versus one that would stimulate an additive mindset among the participants making the judgments. The participants were susceptible to the illusion regardless of scale, but it was different in magnitude depending on judgmental scale. This finding hints that there may be ways to eliminate the negative footprint illusion. Exploring these boundaries is relevant for future research, none the least for testing the generalizability of the negative footprint illusion, the averaging bias and the applied relevance of these phenomena.

## References


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