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Deceptive sustainability: Cognitive bias in people's judgment of the benefits of CO_2 emission cuts

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ABSTRACT

People's beliefs in the actions necessary to reduce anthropogenic carbon dioxide (CO_2) emissions are important to public policy acceptability. The current paper addressed beliefs concerning how periods of small emission cuts contribute to the total CO_2 concentration in the atmosphere, by asking participants to rate the atmospheric CO_2 concentration for various time periods and emission rates. The participants thought that a time period with higher emission rates combined with a period of lower emission rates generates less atmospheric CO_2 in total, compared to the period with high emission rates alone – demonstrating a negative footprint illusion (Study 1). The participants appeared to base their CO_2 estimates on the average, rather than on the accumulated sum, of the two periods' emissions – i.e. an averaging bias (Study 2). Moreover, the effect was robust to the wordings of the problem presented to the participants (Study 3). Together, these studies suggest that the averaging bias makes people exaggerate the benefits of small emission cuts. The averaging bias could make people willing to accept policies that reduce emission rates although insufficiently to alleviate global warming.

1. Introduction

Anthropogenic climate change (Figueres et al., 2017; Hansen et al., 2005; IPCC, 2014; Oreskes, 2004) has already raised sea levels (Solomon, 2007), increased global mean temperature (Houghton, 1996) and caused extreme weather events (Meehl et al., 2000), and the consequences risk being even more dramatic in the future. To mitigate global warming and climate change by reducing anthropogenic greenhouse gas (GHG) emissions is thus one of the most important steps to a sustainable future. However, unless corporate and political opinions reinforce necessary national and international regulations of GHG emissions (Zhao, 2017), this will hardly be possible. Because public opinion influences the direction of corporate and political opinion, people's ability to understand and accept the forces behind global warming is essential to take into consideration.

People tend to mentally account for climate change as an object, instead of a process characterized by temporal totality and inertia (Chen, 2011). A consequence of this mental construal is that the stock-flow relationship of CO_2 accumulation in the atmosphere (*the "inflow" via anthropogenic CO_2 emissions, and the "outflow" via natural CO_2 absorption*; Newell, Kary, Moore, & Gonzalez, 2016, p. 138) becomes difficult to grasp (e.g., Chen, 2011). For example, people tend to mistakenly believe that it is possible to stabilize atmospheric CO_2 by keeping the anthropogenic emissions at current rates (Sterman & Booth Sweeney, 2007). The fundamental limitation of people's mental model of global warming is one of the underlying reasons for the erroneous beliefs individuals have about the relationship between the stock of CO_2 in the atmosphere, the inflow *via* anthropogenic CO_2 emissions, and the outflow *via* natural CO_2 absorption. The belief that the CO_2 concentration can stabilize by keeping CO_2 emissions at current rates fails to take the process of accumulation into consideration. Maintenance of current emission rates in fact result in a continuous accumulation of CO_2 in the atmosphere, as long as the emission rates are higher than absorption rates. This insufficient understanding of climate change may be one reason for people's reluctance to take costly and immediate actions to respond to climate change, as people's understanding and perception of climate change, its mechanisms and consequences appears to be one factor that drives climate action and behavioral responses to this phenomenon (Gifford, 2011).

People's views of climate change and global warming are affected by biases and are easily influenced by extraneous information (Schuldt, Konrath, & Schwarz, 2011). For example, people are more likely to

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believe in global warming on hot days (Zaval, Keenan, Johnson, & Weber, 2014); they respond differently to the threats of climate change depending on perceived distance to the problem (Ejelöv, Hansla, Bergquist, & Nilsson, 2018); and people tend to think that "environmentally friendly" objects can compensate for more harmful ones (a negative footprint illusion; Holmgren, Andersson, & Sörqvist, 2018a,b). This paper extends research on the negative footprint illusion by exploring it in the context of people's beliefs regarding benefits of small emission cuts.

People tend to think that 'climate friendly' behaviors can compensate for less friendly behaviors (Kaklamanou, Jones, Webb, & Walker, 2015; Sörqvist & Langeborg, 2019). For example, a common idea is that "I recycle - therefore I can take my car to work". One possible explanation of these beliefs is that people try to find a balance between good and bad deeds (Sachdeva, Iliev, & Medin, 2009). In other words, people tend to use moral licensing (e.g., Mazar & Zhong, 2010), in which they believe that they can license themselves to act immorally after establishing moral credentials. This manifests in relationships between higher fuel efficiency and increased driving distance (Matiaske, Menges, & Spiess, 2012). Similarly, decreased water use due to a water saving campaign, is related to increased electricity usage (Tiefenbeck, Staake, Roth, & Sachs, 2013); and electric car owners generally feel less obliged to act environmental friendly compared to conventional car owners (Klöckner, Nayum, & Mehmetoglu, 2013).

The idea that 'environmentally friendly' or 'climate friendly' behaviors can compensate for less friendly behaviors is sometimes applied to 'friendly' and 'harmful' objects as well. For example, people tend to think that a hamburger combined with an organic apple has a smaller carbon footprint than the hamburger alone (Gorissen & Weijters, 2016), and even experts intuitively think that a set of conventional and "green" buildings are less harmful to the environment compared to the conventional buildings alone (Holmgren, Andersson, & Sörqvist, 2018a). In general terms, when 'environmentally friendly' items are added to a category of 'regular' items, people tend to think that the environmental impact of the category decreases (Holmgren et al., 2018a). This effect is called the negative footprint illusion and is associated with people failing to take into consideration the simple fact that A + B must necessarily be larger than, or equal to, A. The illusion seems to arise because people base their estimates on the average of the items in the set rather than on their sum, i.e. an average bias (Holmgren et al., 2018a). Because people tend to think that "environmentally friendly" objects can compensate for more harmful ones, the estimated environmental impact become the average of the environmental impact of the objects rather than on their aggregated sum (Fig. 1). It should also be mentioned that the illusion has been shown to arise in both between-participants (Gorissen & Weijters, 2016; Holmgren et al., 2018a; Kim & Schuldt, 2018) and within-participants experimental designs (Holmgren, Kabanshi, Marsh, & Sörqvist, 2018b).

The averaging bias may have arised because natural selection has shaped a balancing heuristic that helps humans process the balance between friendly and harmful actions in interpersonal relationships (Sörqvist & Langeborg, 2019). This heuristic works well when applied to the type of problem it is supposed to solve, but when applied to process the balance between environmentally harmful and environmentally friendly actions, it leads to erroneous thinking because environmentally harmful and friendly actions do not cancel each other out the way harmful and friendly behavior can do in a human relationships.

In this paper, we integrate research on mental models of climate change and global warming (Chen, 2011; Newell et al., 2016) with research on the negative footprint illusion (Holmgren et al., 2018a; 2018b). Specifically, we aim to extend the research on the negative footprint illusion by exploring whether the illusion can arise in the context of people's thinking about the potential benefits of emission cuts. Furthermore, we explored whether the averaging bias underpins inaccurate thinking about these benefits. Study 1 tested whether people neglect the accumulation process and believe that small CO_2 emission cuts improve upon accumulated CO_2 in the atmosphere, even though the cuts are too insufficient to allow for natural CO_2 absorption. Study 2 was designed to test whether an averaging bias underpins this inaccurate thought pattern; and Study 3 tested whether the inaccurate thought pattern is triggered by the way the problem is framed to the participants.

2. Study 1

Past research on the negative footprint illusion has shown that people tend to think that the environmental impact of a set of bad and even worse items, in combination, is better for the environment than the worse items alone. By analogy, Study 1 explored people's estimates of atmospheric CO_2 concentration for a combination of times periods with bad and even worse emission rates compared to the time period with worse emission rates alone. A negative footprint illusion in this context would arise if participants would assign a *lower* atmospheric CO_2 concentration value to the combined set.

All participants were asked to read two scenarios and subsequently estimate the atmospheric CO_2 concentration that would result from the given premises. One scenario stated that mankind contributed about 2 PPM/year of CO_2 during a 5 year period (henceforth called the *'high scenario'*), whereas the other scenario stated that mankind contributed about 2 PPM/year of CO_2 during a 5 year period, but after environmentally friendly interventions contributed about 1.4 PPM/year of CO_2 during an additional 5 year period (henceforth called the *'high + low scenario'*). See Fig. 2 for a visual representation of the two scenarios. We expected to find a negative footprint illusion, such that the participants would inaccurately think the high + low scenario contributes less to the CO_2 concentration in the atmosphere compared to the high scenario.

3. Method – study 1

3.1. Participants

A total of 20 students (50% women) from a Swedish university participated in the study (mean age = 26.15, *SD* = 4.48). The sample size was deemed sufficient based on piloting experiments where effects were obtained with similar sample sizes. All studies reported in this paper were conducted in accordance with the ethical guidelines given by the American Psychological Association and the declaration of Helsinki. The data collectors took note of informed oral consent.

3.2. Materials

A questionnaire was used to obtain data. The participants first read the information on the first page, which stated that they were about to make two evaluations and were asked to read all information carefully before making any judgment. The participants were then presented with a short text about global warming which read: *"Global warming can be defined as the rise of the average temperature of the Earth's climate system and its related effects. Studies show that increase in carbon dioxide (CO_2) emissions contribute to global warming. Anticipated effects include increasing global temperatures, rising sea levels and abnormal weather patterns (For example increased hurricanes and storms). Global warming is influenced by the atmospheric concentration of carbon dioxide (CO_2). For example, the higher the increase of the atmospheric concentration of CO_2, the faster the average temperature will rise. The atmospheric concentration of carbon dioxide (CO_2) is usually reported in 'parts per million' (PPM) and the current concentration is around 407 PPM."* After they had read the information about global warming they were presented with two different scenarios. The first scenario read: *"During 5 years, the contribution of carbon emissions to the atmospheric concentration was relatively high (2 PPM CO_2/year) due to humanity's consumption and use of resources. Please*

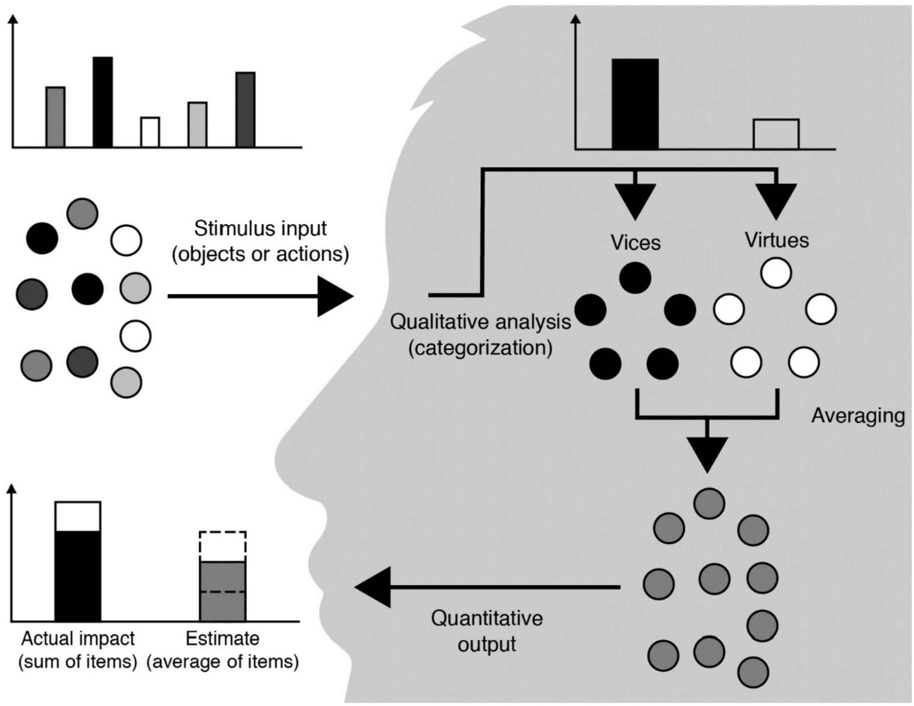

Fig. 1. The figure shows the averaging process. The process begins with stimulus input. The input can be external objects in the surrounding environment or internal thoughts or memories. The human brain tends to classify information based on dichotomies, such as "good" versus "bad", "friend" or "foe", "environmentally friendly" or "harmful", "us" or "them", "virtues" or "vices". The brain analyzes the stimulus input's qualities and classifies the input into this dichotomization system. When the brain is asked to produce an output based on the total stimulus set (not on the individual sets, but the two sets in combination), such as an estimate of the environmental impact of environmentally friendly and harmful objects in combination, the brain applies information processing heuristics to accomplish this task. Such heuristics are hardwired tools in the brain, which makes information processing efficient, pragmatically successful and inexpensive. At the same time, these heuristics can result in erroneous thinking when applied to a type of problem they are not designed to solve. When the brain prepares the quantitative output—the environmental impact estimate—it averages the impact of the environmentally friendly and harmful objects. The product of this information processing chain—the estimate—is the average of the items in the combined set, not the sum of the items.

estimate, to the best of your abilities, how this scenario influences the total atmospheric concentration of carbon dioxide within the given 5 year period by marking the scale below with an 'A'." The second scenario read: *"During 5 years, the contribution of carbon emissions to the atmospheric concentration was relatively high (2 PPM CO_2/year) due to humanity's consumption and use of resources, but after implementations for reducing humanity's environmental impact (*e.g., *replacing fossil fuels with renewable fuels) followed a 5 year period when the contribution of carbon emissions to the atmospheric concentration was relatively low (1.4 PPM CO_2/year). Please estimate, to the best of your abilities, how this scenario influences the total atmospheric concentration of carbon dioxide within the given 10 year period by marking the scale below with a 'B'."* They were asked to estimate the two scenarios hypothetical contribution to the atmospheric concentration of carbon dioxide on the same scale ranging from −7 (decreases the total atmospheric concentration of carbon dioxide), 0 (no contribution), to 7 (increases the total atmospheric concentration of carbon dioxide).

3.3. Design and procedure

A within participants design was used with one independent variable. The independent variable was 'type of scenario' with two levels: the high scenario vs. the high + low scenario. The order between the two scenario types was counterbalanced between participants.

4. Result and discussion – study 1

As can be seen in Fig. 3, the participants reported a lower contribution to the atmospheric CO_2 concentration for the high + low scenario (i.e., 2 PPM/year for 5 years +1.4 PPM/year for another 5 years) compared to the high scenario (i.e., 2 PPM/year for 5 years). This difference between the two conditions was statistically significant as shown with a paired samples *t*-test, $t(19) = 5.19$, $p < .001$, $d = 0.80$, 95% CI [0.89, 3.49]. The results from Study 1 demonstrates that a negative footprint illusion can be found within the context of people's mental models of CO_2 accumulation in the atmosphere, just as previously shown in the context of carbon footprint estimates of food products (Gorissen & Weijters, 2016) and buildings (Holmgren et al., 2018a; 2018b).

5. Study 2

The results in Study 1 indicate that people believe that a five year period of 2 PPM/year of CO_2 together with a subsequent, notably more environmentally sustainable five year period of 1.4 PPM/year of CO_2 contribute less to the atmospheric concentration of CO_2 compared to a single five year period of 2 PPM/year of CO_2. The purpose of Study 2 was to explore whether an averaging bias underpins this negative footprint illusion. If this is the case, then the estimated contribution of the atmospheric concentration of CO_2 of the high + low scenario should fall between estimates of the high scenario and the estimates of a 'low' scenario (1.4 PPM/year of CO_2 for a 5 year period alone). To explore this possibility, Study 2 included the same two scenarios as in Study 1 while also including a third scenario that comprised a 5-year period with an emission rate of 1.4 PPM/year of CO_2. See Fig. 2 for a visual representation of the three scenarios. Evidence for the averaging bias would be revealed if participants would assign lower estimates to the high + low scenario than to the high scenario and higher compared to the low scenario.

6. Method – study 2

6.1. Participants

A total of 47 students (47% women) from a Swedish university participated in the study (mean age = 29.32, *SD* = 7.84). None of them participated in Study 1.

6.2. Materials

The questionnaire was identical to the one in Study 1 except for an addition of one more scenario, which stated: *"During 5 years, the contribution of carbon emissions to the atmospheric concentration was relatively low (1.4 PPM CO_2/year) due to implementations for reducing humanity's environmental impact (*e.g., *replacing fossil fuels with renewable fuels). Please estimate, to the best of your abilities, how this scenario influences the total atmospheric concentration of carbon dioxide within the given 5 year period by marking the scale below with a 'C'."*

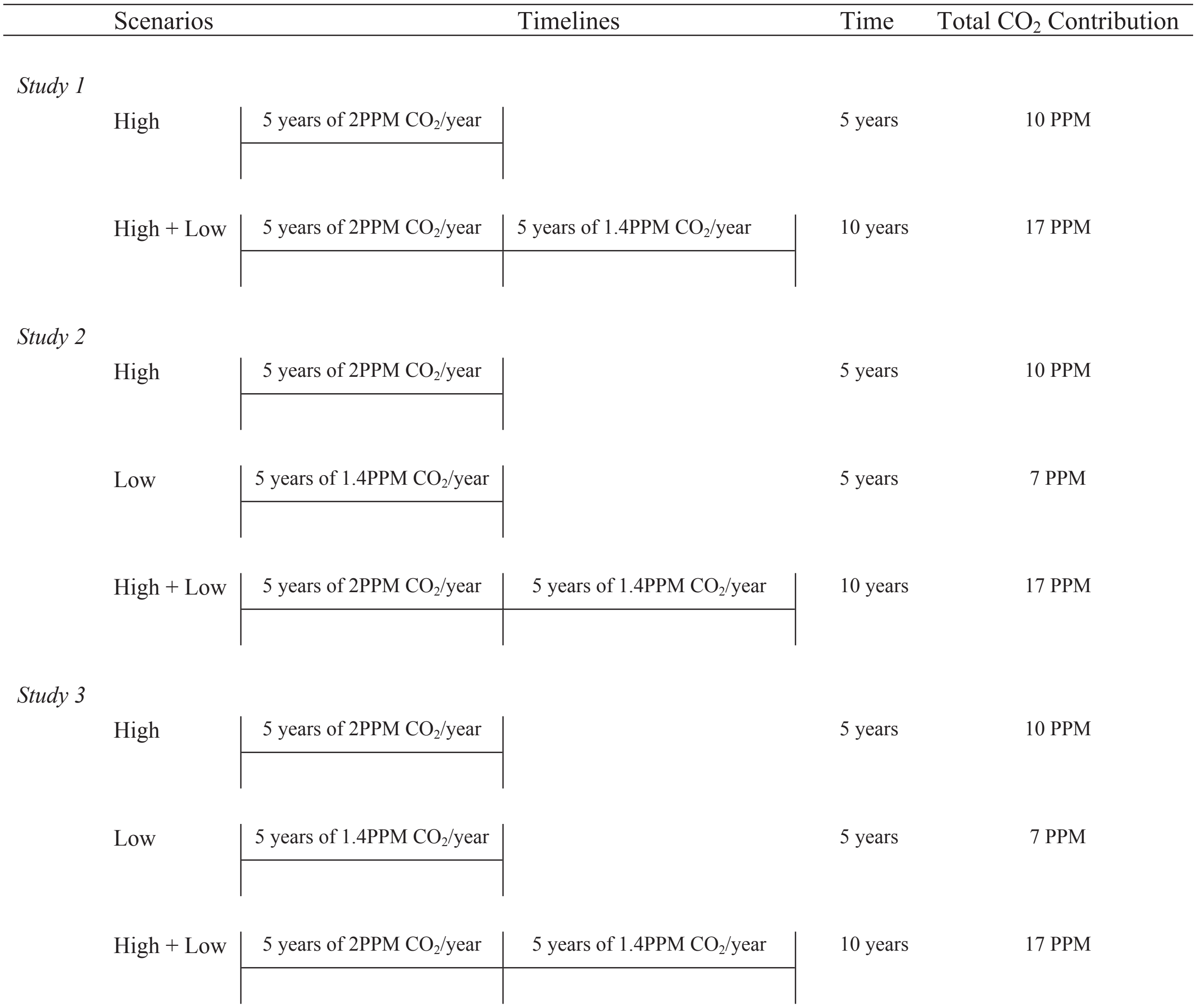

Fig. 2. The figure shows a visual representation of the scenarios in Study 1, Study 2 and Study 3, respectively. It further shows the amount of time and the total CO_2 contribution to the atmospheric CO_2 concentration for each scenario.

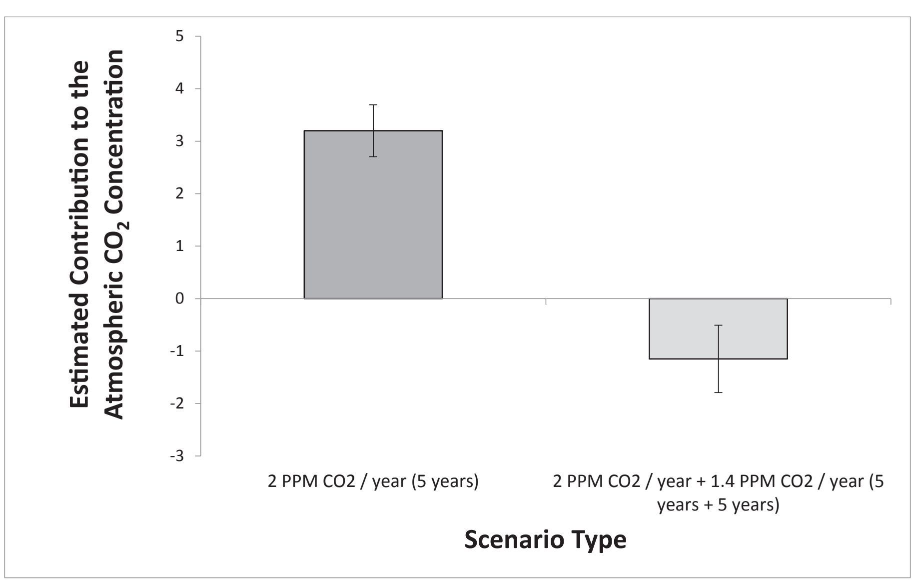

Fig. 3. Estimates of each scenario's contribution to the total atmospheric concentration of carbon dioxide within the given time period in Experiment 1. Error bars represent standard error of means.

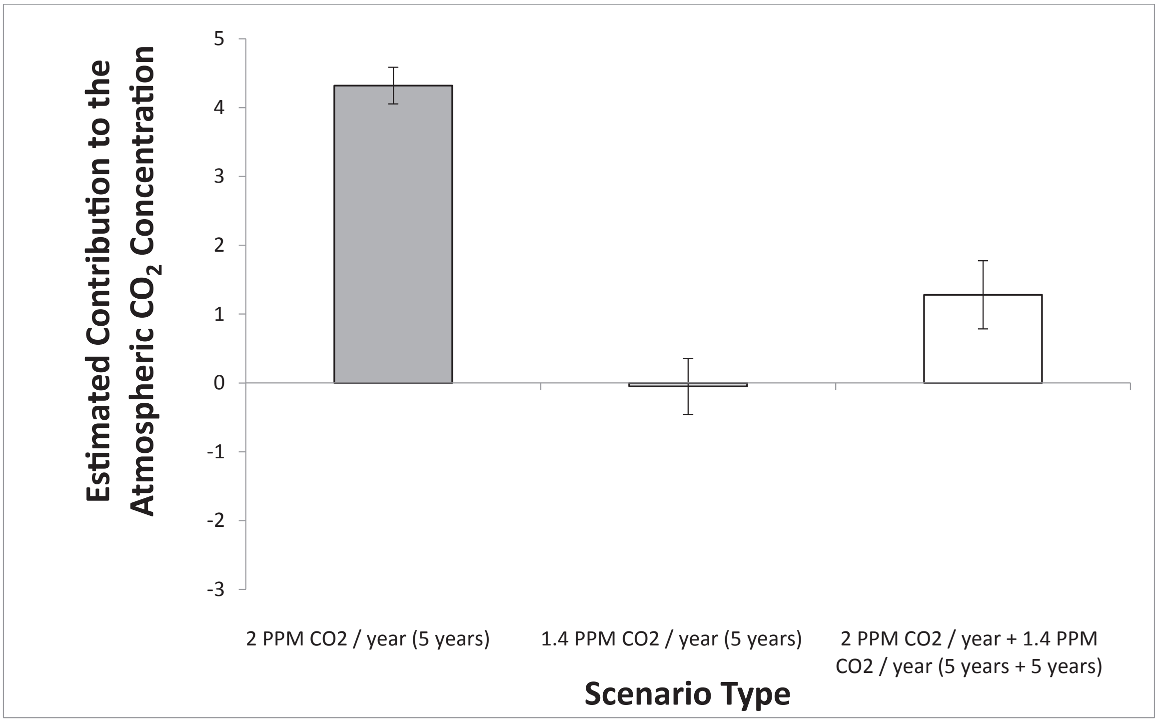

Fig. 4. Estimates of each scenario's contribution to the total atmospheric concentration of carbon dioxide within the given time period in Experiment 2. Error bars represent standard error of means.

6.3. Design and procedure

A within participants design was used with one independent variable. The independent variable was 'type of scenario' with three levels: the 'high scenario' vs. the 'high + low' scenario vs. a contribution about 1.4 PPM/year of CO_2 for five years into the atmospheric concentration (henceforth called the *'low scenario'*). The order between the three scenario types was counterbalanced between participants. Moreover, in this experiment we included an inclusion criterion: three participants who failed to estimate the low scenario as a lower contributor than the high scenario were excluded from the analyses because they either evidently misunderstood the instructions or responded without care.

7. Result and discussion – study 2

As can be seen in Fig. 4, the participants thought that the CO_2 atmospheric contribution for the high + low scenario fell between the other two scenarios. A repeated measures analysis of variance was calculated with scenario type as the independent variable. The analysis revealed a significant difference between conditions, $F(2, 86) = 49.52$, $p < .001$, $\eta_p^2 = 0.54$. Paired samples *t*-tests revealed that the participants estimated the high scenario (i.e., 2 PPM/year for five years) as having a greater contribution to the atmospheric CO_2 concentration compared to the low scenario (i.e., 1.4 PPM/year for five years), $t(43) = 9.66$, $p < .001$, $d = 1.92$, 95% CI [3.45, 5.27], and the high + low scenario (i.e., 2 PPM/year for 5 years +1.4 PPM/year for another 5 years), $t(43) = 6.47$, $p < .001$, $d = 1.15$, 95% CI [2.09, 3.98],. Furthermore, the high + low scenario was estimated as having a higher contribution to the atmospheric CO_2 concentration compared to the low scenario, $t(43) = 3.12$, $p = .003$, $d = 0.44$, 95% CI [0.47, 2.19]. The results from Study 2 replicated the finding from Study 1. In addition, it found evidence for the suggestion that an averaging process underpins people's inaccurate mental models of the benefits of CO_2 emission cuts.

7.1. Study 3

One possibility is that the negative footprint illusion of the benefits of emission cuts arises because words such as "sustainability interventions" in the information provided to the participants trigger the idea that 'better' time-periods can compensate for 'worse' time-periods. The purpose of Study 3 was to explore whether the negative footprint illusion arises even when such symbolically significant information (Sütterlin & Siegrist, 2014) is removed from the information provided to the participants. The participants in Study 3 were given the same scenarios presented in Study 2, with the exception that the information stating "*… due to implementations for reducing humanity's environmental impact* (e.g., *replacing fossil fuels with renewable fuels)*" was removed from both the low and the high + low scenario.

8. Method – study 3

8.1. Participants

A total of 29 students (21% women) from a Swedish university participated in the study (mean age = 25.14, *SD* = 5.50). None of them participated in Study 1 or Study 2.

8.2. Materials

The questionnaire was identical to the one in Study 2 except that the information stating "*… due to implementations for reducing humanity's environmental impact* (e.g., *replacing fossil fuels with renewable fuels)*" was removed from both the low and the high + low scenario. Hence, the low scenario (for example) read: *"During 5 years, the contribution of carbon emissions to the atmospheric concentration was relatively low (1.4 PPM CO_2/year) due to humanity's consumption and use of resources. Please estimate, to the best of your abilities, how this scenario influences the total atmospheric concentration of carbon dioxide within the given 5 year period by marking the scale below with a 'C'."*

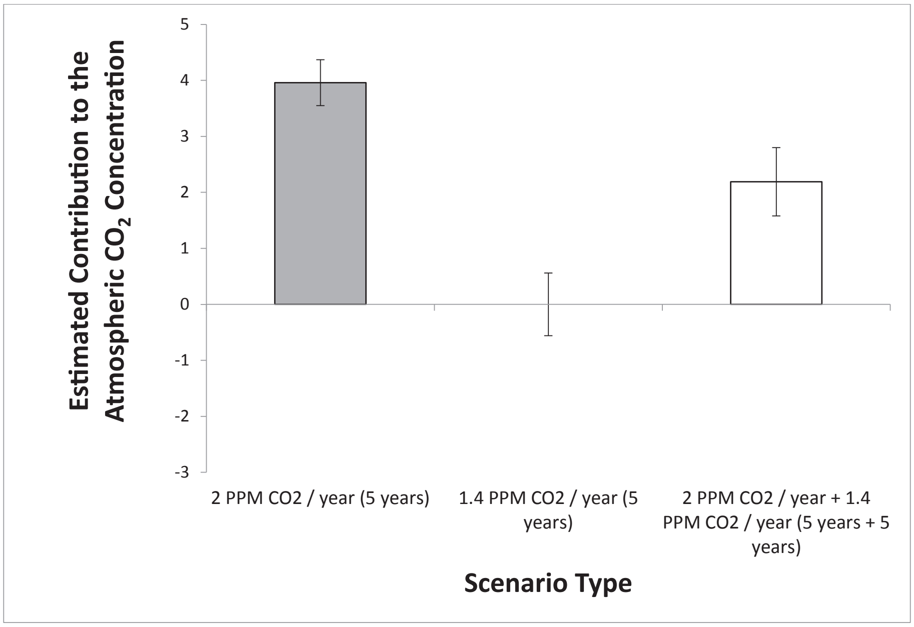

Fig. 5. Estimates of each scenario's contribution to the total atmospheric concentration of carbon dioxide within the given time period in Experiment 3. Error bars represent standard error of means.

8.3. Design and procedure

A within participants design was used with one independent variable. The independent variable was 'type of scenario' with three levels: the 'high scenario' vs. the 'high + low' scenario vs. the low scenario (see Fig. 2). The order between the three scenario types was counterbalanced between participants. The same inclusion criterion used in Study 2 was used in this study. Three participants who failed to estimate the 'low' scenario as a lower contributor than the 'high' scenario were excluded from the analyses.

9. Result and discussion – study 3

As in Study 2, the participants estimated the CO_2 atmospheric contribution for the high + low scenario to fall between the other two scenarios (Fig. 5). A repeated measures analysis of variance was calculated with scenario type as the independent variable. The analysis revealed a significant difference between conditions, $F(2, 50) = 20.88$, $p < .001$, $\eta_p^2 = 0.46$. Paired samples *t*-tests revealed that the participants estimated the high scenario (i.e., 2 PPM/year for five years) as having a greater contribution to the atmospheric CO_2 concentration compared to the low scenario (i.e., 1.4 PPM/year for five years), $t(25) = 8.17$, $p < .001$ $d = 1.59$, 95% CI [2.96, 4.96], and the high + low scenario (i.e., 2 PPM/year for 5 years +1.4 PPM/year for another 5 years), $t(25) = 2.50$, $p = .019$, $d = 0.67$, 95% CI [0.31, 3.22]. Furthermore, the high + low scenario was estimated as having a higher contribution to the atmospheric CO_2 concentration compared to the low scenario, $t(25) = 3.48$, $p = .002$, $d = 0.70$, 95% CI [0.89, 3.49].

The results from Study 3 hence replicated the key findings from Study 1 and Study 2. The study provides further evidence for the assumption that an averaging bias underpins people's mental models of the benefits of emission cuts and suggests that the negative footprint illusion is insensitive to (at least some) symbolically significant information in the framing of the problem.

10. General discussion

The series of studies reported here extends the negative footprint illusion to people's mental models of CO_2 accumulation in the atmosphere. We show that a cognitive bias leads people to think that short period of high CO_2 emissions, followed by an equally short period of low emissions, contribute less to the total concentration of CO_2 in the atmosphere, than a single short period of high emissions alone (Studies 1 and 2). Moreover, the negative footprint illusion is not dependent on the wording by which the problem is framed to the participants, but rather appears to reflect a more basic and robust thought-pattern (Study 3). These results indicate that people believe years of high emission rates can be compensated by years of lower emission rates, even if these years of lower emission rates hardly reverse global warming.

In past studies on the negative footprint illusion (Gorissen & Weijters, 2016; Holmgren et al., 2018b, 2018a; Kim & Schuldt, 2018), participants were asked to estimate the environmental impact of regular and "green" objects in combination (A + B), regular objects alone (A) and "green" objects alone (B). The general finding has been that combinations of regular and "green" objects are assigned lower environmental impact values than regular items alone, as if A + B is less than A. The results of the studies reported here follow the same pattern. Participants tend to think that two time periods of high and low emission rates respectively (A + B) result in a lower atmospheric CO_2 concentration than the time period with high emission rates alone (A). Just as with estimates of environmental impact of objects (Holmgren et al., 2018a), the cognitive mechanism underpinning this thought pattern appears to be an averaging bias. Furthermore, unlike previous research on the negative footprint illusion, this paper adds on previous research suggesting that people do not have an accurate understanding of the stock-flow relationship of CO_2 in the atmosphere (e.g., Sterman & Booth Sweeney, 2007) and that the averaging bias may be responsible for this to some extent.

Furthermore, the presence of the averaging bias indicates that people's inaccurate mental construal is a consequence of intuitive reasoning. Reasoning can, according to Kahneman (2011), be dichotomized into two different systems. System 1 is intuitive, characterized as non-conscious and automatic, and is susceptible to biases; whereas System 2 is conscious, controlled and less prone to biases (Evans & Stanovich, 2013; Kahneman, 2011). Judgments under uncertainty often are often underpinned by intuitive heuristics (characterized by System 1; Tversky & Kahneman, 1983). The data reported here seem to suggest that the participants based their estimates on intuition and their responses a result of System 1, since their responses appear to reflect the averaging bias.

10.1. Applied implications

Most environmental problems can be classified as "wicked" (Rittel & Webber, 1973), by being interconnected in such a way that they have emergent properties that cannot solely be understood by their constituent parts (Miller, 1999). Some scholars even characterize climate change as a "super wicked problem" because of the enormous interdependencies with economic growth and desired life-styles in combination with vast uncertainties involved in finding adequate solutions to it (Lazarus, 2009; Levin, Cashore, Bernstein, & Auld, 2012). The studies elaborated on in this paper are in accord with such a characterization, suggesting that human cognition is limited in its ability to comprehend the mechanics of climate change and pro-environmental reasoning, even when such mechanics seem trivial in a rational sense.

Environmental experts and climate-change scholars often argue that we need more robust climate related data (Bai et al., 2018), and more energy efficient technologies to meet the 2015 Paris climate agreement (Figueres et al., 2017). However, to reach the target of decarbonizing the world economy, psychological issues underlying human behavior, like the one elaborated on herein, appears as an equally critically issue to address in future climate change research (Stoknes, 2015; Thollander & Palm, 2013). We therefore concur with the view of Ürge-Vorsatz et al. (2018) that climate-change mitigation cannot primarily be based on investments in 'low-hanging fruits' with fast returns, such as investments in energy-efficient technologies which lead to insufficient emission cuts, since it can hamper more systemic approaches to be developed with higher mitigation capacity. As our studies suggest, approaches to deal with climate change need also be based on investing in innovative solutions that address cognitive barriers in people. Perhaps the most important applied implication of the results reported here is that the averaging bias could make people willing to accept policies that reduce emission rates but are insufficient to alleviate global warming.

Xie, Hurlstone, and Walker (2018) found that individual's perception and knowledge of the detrimental effects of CO2-emissions increased markedly after participants partook in group discussions and were exposed to multiple perspectives and the opportunity to communicate face to face. Informal institutions, e.g. social norms, can also help to address global climate change (Nyborg et al., 2016). Hence, group-based learning and norm formation can potentially be an avenue forward to facilitate wider climate-change learning in society and avoid reinforcement of insufficient policies.

People's tendency to balance out environmental-friendly actions or objects from environmentally burdening actions or objects (underpinning the negative footprint illusion) is not only a barrier to sustainable behavior and actions; it also makes it crucial to be cautious with how environmentally friendly actions and objects are labeled and marketed. As long as products and choices are marketed as environmentally friendly, biases like averaging could make people misunderstand the consequences of these products and options, and lead them to believe that products with these labels are good for the environment, rather than simply less bad. For example, people may believe that buying 'environmentally friendly' products does not contribute to the atmospheric CO_2 concentration, even though it does but at a lower rate compared to buying conventional products. One way to overcome this problem is by means of a sharpened legislation concerning 'environmentally friendly' labeling and marketing. In the same way that there are rules regarding claims about the content of food on the packing, there should also be restrictions for use of labels like 'environmental friendly', climate neutral etc. The easiest way to achieve this would probably be to use regulations for each of these labels, in the same way as for example for the euro leaf for organic products.

10.2. Limitations

The participants in the current studies were asked to estimate the contribution to the total CO_2 concentration from emissions during given time period(s). This task is cognitively taxing, both because the different scenarios concerned different length of the time periods (5 vs 10 years) and because the contribution to the total CO_2 concentration under the given time period may be harder to estimate than the overall effect. The task used here may have been difficult and perhaps mislead the participants into responding in a way that does not reflect their actual understanding of the CO_2 accumulation problem. However, the similarity between the results obtained here and the results obtained in past research on the negative footprint illusion suggest that the results cannot be explained by task difficulty alone. Estimating the environmental impact of "green" and regular buildings in comparison with the regular buildings alone is, arguably, a relatively simple task, at least in comparison with the task used in the current study. Yet, the thought patterns participants seem to follow are strikingly similar regardless of task and the results of the current study can hardly be rejected as irrelevant because the participants did not understand the task properly: as stated by Gilovich and Griffin (2002, p.12) "… certain misconstruals on the part of participants are not artifacts, they *are* the phenomena of interest". Another aspect that was not considered in the current series of studies was participants' knowledge of the mechanisms of CO_2 accumulation and global warming or other individual measures which might have had an influence on the results (e.g., environmental concern). However, as we have shown earlier, people who have knowledge necessary to make accurate judgment are not necessarily immune to the negative footprint illusion (Holmgren et al., 2018b).

11. Conclusions

Heuristics and systematic biases of the human mind lead to misconceptions about climate change and global warming. We need to develop more effective educational approaches to overcome the barrier of human cognition in order to avoid wicked outcomes in solving environmental problems. Campaigns and consumer information based solely on scientific rationales seem quite ineffective (Stoknes, 2015). For one thing, policy makers, planners and climate-change researchers need to package the message of global warming in more effective ways. As shown here, insights developed within the subject area of environmental psychology have much to offer in this context. What might seem to be logical policy interventions may in fact be quite deceptive interferences for achieving sustainability. Hence, strengthened legislations about information concerning emission cuts and 'environmentally friendly' choices could be a necessary tool to overcome the influence that the averaging bias seems to have in people's thinking about the benefits of emission cuts.

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