

Acting green elicits a literal warm glow

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Environmental policies are often based on the assumption that people only act environmentally friendly if some extrinsic reward is implicated, usually money^{1,2}. We argue that people might also be motivated by intrinsic rewards: doing the right thing (such as acting environmentally friendly) elicits psychological rewards in the form of positive feelings, a phenomenon known as warm glow^{3,4}. Given the fact that people's psychological state may affect their thermal state^{5,6}, we expected that this warm glow could express itself quite literally: people who act environmentally friendly may perceive the temperature to be higher. In two studies, we found that people who learned they acted environmentally friendly perceived a higher temperature than people who learned they acted environmentally unfriendly. The underlying psychological mechanism pertains to the self-concept: learning you acted environmentally friendly signals to yourself that you are a good person. Together, our studies show that acting environmentally friendly can be psychologically rewarding, suggesting that appealing to intrinsic rewards can be an alternative way to encourage pro-environmental actions.

Think about something good you did for the environment, such as walking to a bottle bank to recycle glass. What drove you to do this? Environmental policies often stress extrinsic rewards that people can achieve when acting environmentally friendly, such as saving money. However, in at least some instances, environmental appeals have been more effective in encouraging pro-environmental behaviour than appeals to self-interest^{1,2}. The assumption is that this is the result of pro-environmental behaviour leading to intrinsic rewards. This could explain why people recycle glass, even though no extrinsic rewards are available.

We aim to explore if pro-environmental behaviour is indeed intrinsically rewarding and how this is reflected. Intrinsic rewards can manifest themselves in a warm glow, which people can experience when they feel good about themselves as a result of acting morally^{3,4}. We argue that if acting environmentally friendly is indeed truly intrinsically rewarding, this should be visible in a literal warm glow, in the form of perceiving a higher temperature. Literature suggests that people's psychological state can affect their thermal state in the form of temperature perception^{5,6}. Neurologically, this results from people's insula becoming activated, which affects their temperature perception⁷. The insula is also activated when highly rewarding outcomes are experienced⁷ and when making moral decisions, especially following emotional processing⁸. Initial evidence suggests that pro-environmental behaviour is moral behaviour with an emotional core, such as feeling good about oneself⁹.

We propose that if acting environmentally friendly indeed leads to a literal warm glow, this results from pro-environmental behaviour serving as a positive self-signal^{10,11}, as such behaviour can signal something good about a person. This signalling function of pro-environmental actions boosts one's self-concept

and makes one feel good about oneself, thus being intrinsically rewarding as one's psychological state improves. Hence, if pro-environmental actions are indeed experienced as truly intrinsically rewarding, this should activate the insula and subsequently affect temperature perception (the literal warm glow). This suggests that the warm glow as it was originally formulated^{3,4} is part of the underlying mechanism for pro-environmental actions being intrinsically rewarding, leading to perceiving a higher temperature. If our reasoning is correct, we should first find that compared to people who learn they act environmentally unfriendly, people who learn they act environmentally friendly experience more warm glow in the form of perceiving a higher temperature. Second, we expect that learning that one acts environmentally friendly is intrinsically rewarding, as it serves as a positive self-signal; we test whether this is indeed the process underlying perceiving a higher temperature after acting environmentally friendly. Pro-environmental actions may affect not only perceived, but also actual physical warmth (skin temperature¹²), which we will also explore. Skin temperature can increase by vasodilation and decrease by vasoconstriction—respectively, the widening and narrowing of one's blood vessels. Vasoconstriction occurs faster among women¹³, so if any effects on skin temperature are found, these might be more pronounced for women.

Study 1 examined whether people who learn they act environmentally friendly experience a literal warm glow in the form of perceiving a higher temperature. After completing a carbon footprint calculator, study participants (psychology students) received their carbon footprint and read that the lower their footprint is, the more pro-environmental their behaviour is. Participants in the two experimental conditions also received a bogus carbon footprint of the average student, to reflect that one's behaviour is either relatively environmentally friendly or environmentally unfriendly. For explorative reasons we included a third condition (Comparison group), where participants received only their own carbon footprint, to explore in what way temperature perception is affected when no information on others' footprint was provided. Next, temperature perception was measured⁵: 'How many degrees Celsius do you think it is in this room at this moment?' ($M = 20.22$, $s.d. = 1.73$). Skin temperature was measured every 5 s with iButtons¹⁴. Finally, participants in the experimental conditions indicated whether they believed that they acted relatively environmentally friendly or environmentally unfriendly: 'The average student is more pro-environmental than me' (1 = not true at all, 7 = very true; manipulation check). Participants who learned they acted relatively environmentally unfriendly ($M = 5.28$, $s.d. = 1.66$, 95% CI [4.89, 5.67]) indeed saw the average student as more pro-environmental than themselves, compared to participants learning they acted relatively environmentally friendly ($M = 2.65$, $s.d. = 1.58$, 95% CI [2.27, 3.02]): $F(1,141) = 94.06$, $p < 0.001$, $\eta_p^2 = 0.40$.

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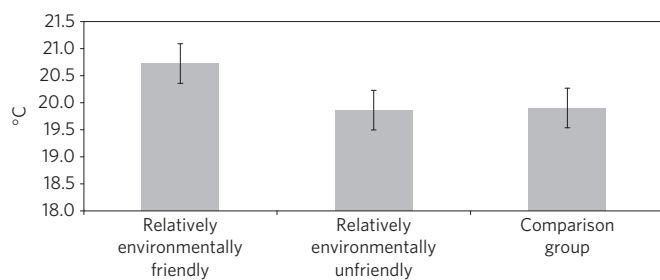


Figure 1 | Means of temperature perception (including standard error bars; Study 1).

Analysis of variance (ANOVA) showed that temperature perception differed significantly between the conditions: $F(1,174) = 5.36, p = 0.006, \eta_p^2 = 0.058$. As expected, participants learning they acted relatively environmentally friendly perceived a higher temperature ($M = 20.72, s.d. = 1.56, 95\% \text{ CI } [20.35, 21.09]$) than participants learning they acted relatively environmentally unfriendly ($M = 19.86, s.d. = 1.60, 95\% \text{ CI } [19.48, 20.23]$): Contrast = 0.86, $p = 0.003$, Cohen's $d = 0.54$, and compared to participants in the comparison group ($M = 19.90, s.d. = 2.11, 95\% \text{ CI } [19.16, 20.63]$): Contrast = 0.82, $p = 0.021$, Cohen's $d = 0.44$. There was no significant difference in temperature perception between participants learning they acted relatively environmentally unfriendly ($M = 19.86, s.d. = 1.60$) and those in the comparison group ($M = 19.90, s.d. = 2.11$): Contrast = $-0.04, p = 0.913$, Cohen's $d = 0.02$ (Fig. 1).

Repeated measures ANOVA (Greenhouse Geisser corrected) revealed no significant difference in skin temperature development between the conditions: $F(3.58, 304.36) = 0.808, p = 0.509, \eta_p^2 = 0.009$, although there was a significant difference regarding women's skin temperature: $F(3.66, 201.39) = 2.799, p = 0.031, \eta_p^2 = 0.048$ (Fig. 2; $t_1 =$ moment that participants received their carbon footprint). Women learning that they acted relatively environmentally friendly showed a relative increase in skin temperature after t_1 compared to women who learned they acted environmentally unfriendly ($F(1.97, 181.63) = 3.663, p = 0.028, \eta_p^2 = 0.038$) and those in the comparison group ($F(1.49, 89.45) = 3.382, p = 0.052, \eta_p^2 = 0.053$). There was no significant difference in skin temperature development between women who learned they acted relatively environmentally unfriendly and those in the comparison group: $F(2.11, 143.63) = 0.858, p = 0.431, \eta_p^2 = 0.012$. The development of men's skin temperature did not differ between conditions: $F(3.44, 96.42) = 1.833, p = 0.138, \eta_p^2 = 0.061$.

Study 2 builds on the findings of Study 1, by also testing the extent to which acting environmentally friendly serves as a positive self-signal, in turn leading to the literal warm glow. The design of Study 2 was similar to that of Study 1. However, Study 2 did not include a comparison group and was conducted in a climate-controlled room where the actual room temperature was held constant at 20°C . Immediately after participants saw their carbon footprint relative to others, we measured the extent to which this carbon footprint served as a positive self-signal before measuring temperature perception. Participants learning they acted relatively environmentally friendly indeed saw the average student as less pro-environmental than themselves ($M = 3.00, s.d. = 1.43, 95\% \text{ CI } [2.55, 3.45]$), compared to participants learning they acted relatively environmentally unfriendly ($M = 4.28, s.d. = 1.70, 95\% \text{ CI } [3.73, 4.83]$): $F(1,78) = 13.35, p < 0.001, \eta_p^2 = 0.146$.

As hypothesized, we again found that participants learning they acted relatively environmentally friendly perceived the room temperature to be higher ($M = 20.23, s.d. = 1.18, 95\% \text{ CI } [19.86, 20.61]$) than participants learning they acted

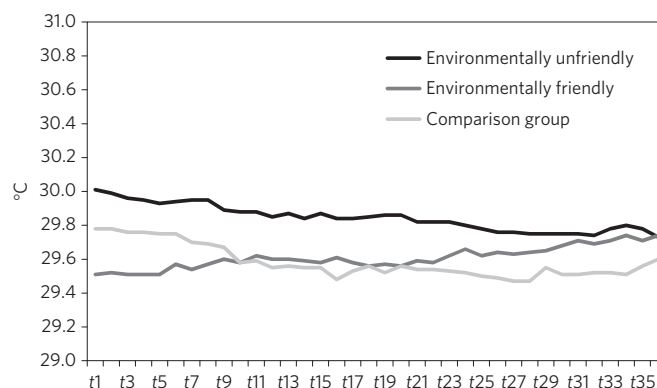


Figure 2 | Skin temperature change among women (Study 1).

relatively environmentally unfriendly ($M = 19.49, s.d. = 1.66, 95\% \text{ CI } [18.96, 20.03]$): $F(1,78) = 5.28, p = 0.024, \eta_p^2 = 0.063$ (Fig. 3). We found no significant difference in skin temperature development between participants learning they acted relatively environmentally friendly and those who learned they acted relatively environmentally unfriendly: $F(1.42, 109.00) = 0.483, p = 0.553, \eta_p^2 = 0.006$, both for women ($F(1.54, 98.44) = 2.199, p = 0.464, \eta_p^2 = 0.011$) and men ($F(1.19, 13.07) = 0.307, p = 0.628, \eta_p^2 = 0.027$).

A mediation analysis¹⁵ was conducted to test whether acting environmentally friendly (versus environmentally unfriendly) indeed signals something positive (versus negative) about oneself, in turn affecting one's temperature perception. Indeed, people who learned they acted relatively environmentally friendly derived a more positive self-signal out of their carbon footprint than people learning they acted relatively environmentally unfriendly: $\beta = 0.82, t = 12.42, p < 0.001$. As predicted, a stronger positive self-signal was associated with perceiving a higher temperature: $\beta = 0.38, t = 2.062, p = 0.043$. The bias-corrected bootstrap estimate of the indirect effect had a 95% confidence interval from -0.929 to -0.024 . The direct effect of acting environmentally friendly (versus environmentally unfriendly) on perceived temperature was no longer significant when the strength of the positive self-signal was included in the model as well: $\beta = 0.060, t = 0.323, p = 0.748$ (Fig. 4). This indicates that, as expected, the literal warm glow that people experience results from the positive self-signal that people derive out of acting relatively environmentally friendly.

In both studies, we found that people who learned they acted environmentally friendly perceived the temperature to be higher than people who learned they acted environmentally unfriendly. This was the result of acting environmentally friendly serving as a positive self-signal (Study 2). The signalling function of pro-environmental behaviour thus appears to make pro-environmental behaviour intrinsically rewarding: acting environmentally friendly boosts a person's self-concept, which is reflected in a literal warm glow. We also explored whether physical warmth (skin temperature) is affected by acting environmentally friendly, but we found no consistent evidence for this. Earlier research did find a relation between one's psychological state and physical warmth, albeit in a different domain (social relations)¹². As the effects of one's psychological state on skin temperature may be relatively small, future research could enhance the power by using larger samples or even more accurate devices; the accuracy of the iButtons is 0.09°C (ref. 14), the accuracy of devices used in earlier work is 0.03125°C (ref. 12).

Our findings extend research that showed that environmental appeals can be more effective than appeals to extrinsic rewards^{1,2}, because pro-environmental actions may provide intrinsic rewards. We showed that the latter is indeed true, as reflected in a literal warm

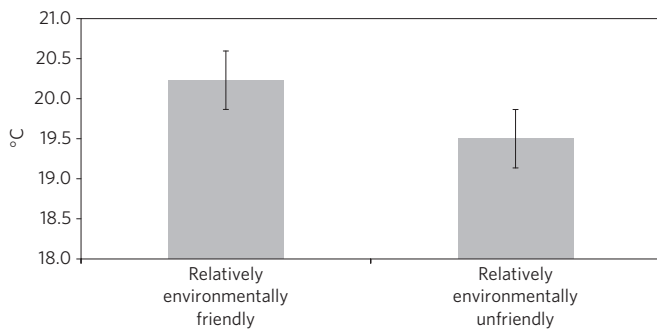


Figure 3 | Means of temperature perception (including standard error bars; Study 2).

glow that results from a boost of one's self-concept. Campaigns could stress that pro-environmental actions are intrinsically rewarding ('you can contribute to protecting the environment by unplugging electronic devices you don't use'), instead of appealing to extrinsic rewards ('you save \$43 annually by unplugging electronic devices you don't use').

To our knowledge, this paper is the first to show that doing good in the environmental domain can lead to higher perceived temperatures, suggesting that warm glow as it was originally formulated^{3,4} can express itself literally. Several points can be raised regarding the generalizability of our findings. First, our sample comprised psychology students: young, mostly female and highly educated people. One could speculate that this sample has relatively strong environmental values, making pro-environmental actions relatively important to the self¹⁶, and in turn more likely to increase perceived temperatures. Future studies should include different samples to explore possible individual differences (for example, in environmental values) in the extent to which acting environmentally friendly affects temperature perception. Second, we showed people's carbon footprint relative to others to communicate how environmentally friendly people acted. This social comparison component may have affected our findings, as the effects of one's psychological state on temperature perception can be based on social considerations^{7,12}. Future research could test this, by making salient how environmentally friendly someone acted without inducing social comparison. For example, recycling may, in particular, lead to a literal warm glow when you simultaneously see other people acting environmentally unfriendly. Third, it would be interesting to see whether other good behaviours also lead to a literal warm glow. Based on our reasoning, any action serving as a positive self-signal could increase perceived temperatures, which should not be limited to pro-environmental actions. However, given that particularly social and moral actions activate the insula^{7,8} and the fact that ascription of social and moral personality traits (compared to other types of traits) increase perceived temperatures¹⁷, the strength of the literal warm glow may vary across domains. Fourth, future research could explore to what extent effects of acting environmentally friendly (versus environmentally unfriendly) on temperature perception might affect warmth-related environmental behaviours such as people's thermostat settings. Research revealed that a negative psychological state due to feeling chronically lonely not only results in perceiving a lower temperature, but also in taking warmer showers, presumably to make one feel better⁶. The question remains whether similar effects occur after one's psychological state is affected by learning one acted environmentally friendly.

It is critical to understand why people act environmentally friendly, so as to design more effective environmental policies. We found that acting environmentally friendly boosts the self and is intrinsically rewarding, which can even lead to a literal warm

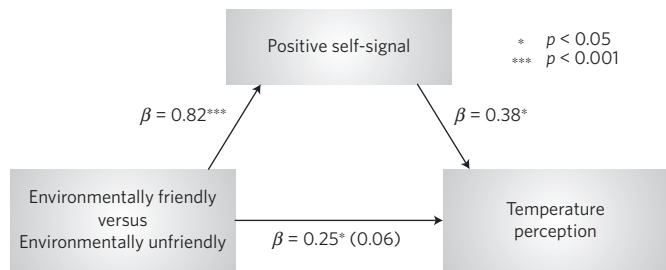


Figure 4 | Mediation model: positive self-signal (Study 2).

glow by affecting how warm a person perceives it to be. This suggests that appealing to intrinsic rewards can help encourage pro-environmental actions.

Methods

Study 1 was conducted in the lab among 180 first-year psychology students at a Dutch university, who participated in return for course credits (age $M = 20.5$, $s.d. = 2.55$, 65.0% female). Three participants were deleted from all analyses; two participants' answers regarding temperature perception deviated more than 4 s.d.'s from the mean and one participant entered the lab with warm coffee, which could affect the study purpose. The carbon footprint calculator that participants completed included questions on travel, energy and eating behaviour. In the two experimental conditions, the average carbon footprint of other students (who had ostensibly completed this carbon footprint calculator in previous experiments) was programmed to always be either 49% lower, or 49% higher than the carbon footprint of the participant. Beneath these footprints it also stated 'Compared to the average student, your carbon footprint is 49% better (worse)', to make salient one's behaviour is either relatively environmentally friendly or environmentally unfriendly. For a different study purpose we systematically varied the composition of the reference group, the groups being environmental sciences students and law students. No differences in the reported results between these two reference groups were found, so only the overall analyses are reported using the label 'average student' throughout Study 1. For explorative reasons we included a third condition (Comparison group), where participants received only their own carbon footprint score. Based on the assumption that absolute carbon footprint scores are generally not very meaningful to people^{18,19} and that people need a reference to determine how environmentally friendly they are actually acting, it was not clear beforehand whether participants in this third condition interpret their carbon footprint as rather low or high, and how their temperature perception is affected. The iButtons¹⁴ used to measure skin temperature are small wireless temperature measuring devices, which were placed on participants' middle finger on the left hand. We did not have skin temperature measurements for four participants: one participant had a broken hand and three participants had removed the iButton before the experiment was finished.

Study 2 was conducted in a climate-controlled room (where the actual room temperature was held constant at 20°C) among 83 first-year psychology students at a Dutch university, who participated in return for course credits (age $M = 20.5$, $s.d. = 3.15$, 84.3% female). Three participants were deleted from all analyses, of which two entered the climate-controlled room with warm coffee in their hands, which could affect the study purpose, while one participant did not finish the entire study. Conducting the study in a climate-controlled room allowed us to control more thoroughly for possible variations in actual room temperature that might occur. This climate-controlled room functions as an independent living unit with, among other things, a workspace, kitchen and bathroom. As a cover story, participants were told that these rooms were newly built and needed to be tested for their comfort, as in future studies other participants would stay in the rooms for multiple days. While participants were testing these rooms, they also completed some studies on the computer for the psychology department.

Participants had two sessions in the climate-controlled room. Only session 2 is discussed in the paper, where participants calculated their carbon footprint and subsequently estimated the room temperature (further tasks included for a different study purpose were: testing the bed and chair in the room, taking a shower, making a cup of tea, and designing brand logos). Again, participants calculated their carbon footprint through the same procedure as in Study 1, with the average psychology student serving as the reference group. Subsequently, participants responded to three statements which measure the extent to which their carbon footprint served as a positive self-signal: 'My carbon footprint says something positive about who I am', 'My carbon footprint gives me a sense of accomplishment' and 'My carbon footprint gives me a positive feeling about myself' (1 = Completely disagree, 7 = Completely agree; $M = 3.49$, $s.d. = 1.91$, $\alpha = 0.97$). Temperature perception and skin temperature were measured in the

same way as in Study 1. We had no skin temperature measurements of one participant who had taken off the iButton before the experiment was finished. The study was concluded with a manipulation check by responding to the statement: 'The average psychology student is more pro-environmental than me' (1 = not true at all, 7 = very true).

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Author contributions

D.T. developed the study concept. All authors contributed to the study design. D.T. performed the data analysis and interpretation under the supervision of J.W.B. and L.S. D.T. drafted the manuscript, and J.W.B. and L.S. provided critical revisions. All authors approved the final version of the manuscript for submission.

Additional information

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Competing financial interests

The authors declare no competing financial interests.