SHORT COMMUNICATION

Climate change images produce an attentional bias associated with pro-environmental disposition

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Abstract

Humans have developed mechanisms to prioritize certain sensory input(s). Emotionally salient stimuli automatically capture observers' attention at the cost of less salient information. This prioritized processing is called attentional bias. Images of climate change have been found to elicit emotional responses. Yet, to date, there is no research assessing the extent to which climate change-relevant images produce an attentional bias. In a sample of college students ($N = 39$), we found that (1) climate change-related images capture attention and that (2) this attentional bias is related to individual differences in environmental disposition. Thus, images of climate change are salient—attention grabbing—signals related to pro-environmental orientation.

Keywords Climate · Dot-probe · Spatial attention · Processing bias · Environmental attitudes · Environmental cognition

Introduction

Humans are incapable of processing all sensory information equally and have therefore developed mechanisms to prioritize certain sensory input(s) at the cost of other inputs. This prioritized processing is referred to as attentional bias, which has been most extensively studied in regard to hypervigilance to threat in anxiety (Macleod et al. 1986; Bar-Haim et al. 2007). However, attentional bias itself is not unique to anxiety. For example, individuals high in positive affectivity tend to "look on the bright side" and display heightened attentional bias to positive emotional stimuli (Grafton et al. 2012). Other information captures attention relatively universally including nonverbal social signals (e.g., facial expressions and eye gaze) as well as threatening and rewarding stimuli (Friesen and Kingstone 1998; Driver et al. 1999; Ohman et al. 2001; Brosch et al. 2007; Fox et al. 2007; Carlson et al. 2009; Carlson and Reinke 2014; Carlson and Mujica-Parodi 2015; Torrence et al. 2017). Thus, attentional biases are observed across a wide variety of circumstances in which a stimulus/cue is perceived to be important/salient to the individual.

Given that one of the most pressing concerns affecting the global community is the increasing impact of anthropogenic climate change (Field et al. 2014), it would be reasonable to expect that images related to this topic (e.g., industrial pollution or natural disasters) would be salient signals that automatically capture attention. Previous research has shown that climate change-related images are emotionally salient (O'Neill and Nicholson-Cole 2009; Leviston et al. 2014; Chapman et al. 2016). Yet, the question of whether these emotionally salient climate-relevant images capture attention remains unanswered. This is primarily because the study of climate images has been restricted to qualitative methods (e.g., focus groups) and self-report approaches (Nicholson-Cole 2005; O'Neill and Nicholson-Cole 2009; O'Neill and Hulme 2009; Chapman et al. 2016). Indeed, within the study of climate imagery, there is limited existent research using objective measures (e.g., cognitive tasks) and no research assessing the extent to which climate images capture attention. Understanding the cognitive mechanisms—such

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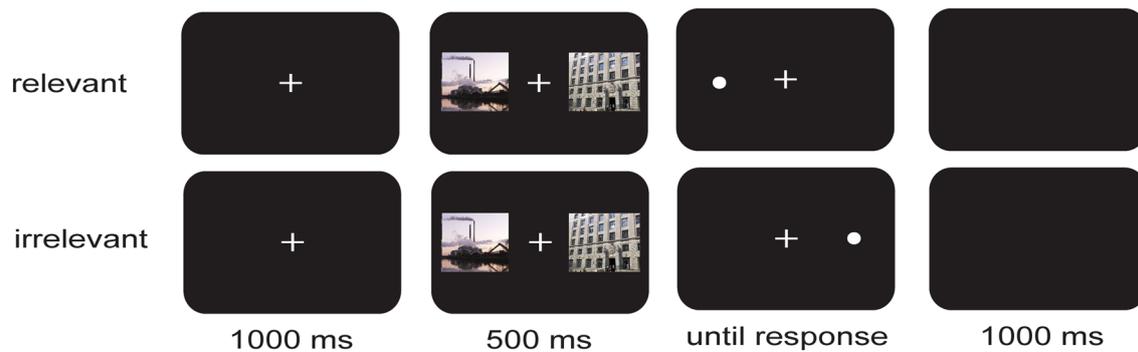
Fig. 1 Examples of climate-relevant and climate-irrelevant trials in the dot-probe task. The climate change-relevant image appeared on the same side as the target dot for climate-relevant trials (50% of trials) and on the opposite side for climate-irrelevant trials (50% of trials). Attentional bias is measured by faster responses on climate-relevant compared to climate-irrelevant trials

as attentional bias—associated with processing climate change-related information is critical in understanding people's action (or inaction) to reduce the effects of climate change. Accordingly, the aims of this investigation were to (1) assess the degree to which emotionally salient climate change-related images capture attention and (2) assess the degree to which attentional bias to climate change-related images relates to pro-environmental attitudes. We hypothesized that emotionally salient climate change-related images would capture attention and that this effect would be larger in individuals with heightened pro-environmental attitudes.

Methods

Participants

Forty-two undergraduate students participated in the study. One participant was excluded for poor accuracy (45% correct vs. $M = 98.67\%$, SD = 1.95%), and two individuals were identified as outliers for having reaction times greater than 3 SDs above the group mean ($M = 370.24$ ms, SD = 39.05 ms). The final sample consisted of 39 (female = 24) individuals between the ages of 18–23 ($M = 19$, SD = 1.43). Based on our previous work (Carlson and Mujica-Parodi 2015; Torrence et al. 2017), we expected a medium effect size in the dot-probe task. Using G*Power 3.1.9.2 with $d = 0.50$ (i.e., Cohen's guideline for a medium effect size; Cohen 1988), $\alpha = 0.05$, and power = 0.80 it was determined that an $N \geq 27$ would be needed to detect the medium sized attention bias effect in the dot-probe task. The study was approved by the Northern Michigan University Institutional Review Board and conducted in accordance with the approved methods. All participants provided informed consent and received course credit for participation.

Stimuli

We used 56 stimuli from a recently amassed database (https://affectiveclimateimages.weebly.com) of 320 images rated for their relevance (1–9 low to high) to climate change as well as their emotional valence (1–9 negative to positive) and arousal (1–9 calm to exciting; Lehman et al. under review). Images used had ratings of either high relevance ($n = 28$, $M = 7.54$, SD = 0.18) or low relevance ($n = 28$, $M = 4.16$, SD = 0.48, $p < .001$) to climate change. Consistent with the notion that climate images are emotionally salient (O'Neill and Nicholson-Cole 2009; Leviston et al. 2014; Chapman et al. 2016), high-relevance images were rated higher in arousal ($M = 5.17$, SD = 0.26, $p < .001$) and negative affect ($M = 3.35$, SD = 1.41, $p < .001$) compared to low-relevance images ($M = 4.34$, SD = 0.50; $M = 4.92$, SD = 1.14, respectively). Climate change-relevant images broadly captured the topic of climate change including its causes (e.g., industrial pollution and deforestation), consequences (e.g., floods and melting ice), and potential solutions (e.g., windmills and solar panels; see supplementary material for all images used). High- and low-relevance images were roughly equated on general content (i.e., people, animals, buildings/manmade structures, and landscapes; all $\chi^2 \leq 2.28$, $p > .1$), brightness ($p > .1$), and visual clutter ($p > .1$; Rosenholtz et al. 2007).

Dot-probe task

The dot-probe task (Macleod et al. 1986; MacLeod and Mathews 1988) was programmed using E-Prime2 (Psychology Software Tools, Pittsburg, PA) and displayed on a 60 Hz 16″ LCD computer monitor. As can be seen in Fig. 1, each trial started with a white fixation cue (+) in the center of a black background for 1000 ms. Two images were then presented simultaneously, one on each side of the fixation cue,

for 500 ms. Images extended $10° \times 12°$ of the visual angle and were separated by $14.5°$ of the visual angle; participants were seated 59 cm from the screen. The target dot appeared immediately after the images were removed and remained on the screen until the participant responded. Participants were instructed to focus on the central fixation cue throughout the trial and respond to the location of the target dot (left or right) as quickly as possible. Participants indicated left-sided targets by pressing the "1" button on a keyboard using their right index finger and indicated right-sided targets by pressing the "2" button using their right middle finger.

Climate-relevant and climate-irrelevant images were randomly presented to the left visual field (LVF) or right visual field (RVF) for each participant. The task included an equal number of trials with the target dot on the same side of the screen as the climate change-relevant image and on the same side as the climate change-irrelevant image. Faster reaction times (RTs) to targets occurring at the climate-relevant location (i.e., congruent) compared to climate-irrelevant location (i.e., incongruent) are considered representative of attentional bias (Macleod et al. 1986; MacLeod and Mathews 1988). There were 180 trials distributed over three blocks.[1] Each block contained 30 (15 LVF & 15 RVF) climate-relevant and 30 (15 LVF & 15 RVF) climate-irrelevant trials. At the end of each block, participants received feedback about their overall accuracy and reaction times to encourage accurate rapid responses.

Questionnaire

The New Ecological Paradigm (NEP) scale contains 15 statements with a Likert-type scale of 1 (strongly disagree) to 5 (strongly agree) to measure pro-environmental orientation. It contains an approximately equal number of pro-environmental ($n = 8$) and anti-environmental ($n = 7$) items. The NEP scale has strong internal consistency and reliability, as well as convergent validity with other environmental views (for questionnaire items and additional information see Dunlap et al. 2000).

Results and discussion

NEPS questionnaire

Six participants did not complete the NEP scale; thus, associated analyses only included $N = 33$. NEP scores ranged

from 38 to 69 ($M = 53.09$, SD $= 7.85$). Age was not correlated with NEP scores, $r(31) = -.16$, $p = .36$ (likely due to our limited age range). However, consistent with the previous research (Dietz et al. 2002), females ($M = 55.73$, SD $= 6.83$) scored higher on the NEP than males ($M = 47.82$, SD $= 7.29$), $t(31) = 3.07$, $p = .004$.

Attentional bias to climate change images measured by the dot-probe task

Data were filtered to only include correct responses between 150 and 750 ms post-target onset to exclude premature responses and lapses in attention (98.29% of the data included; Torrence et al. 2017). Given that sex was related to NEP scores and recent interest in assessing sex differences in attentional bias (Campbell and Muncer 2017; Carlson et al. 2018), sex was considered as an exploratory factor of interest. A 2×2 mixed factors analysis of variance (ANOVA) was used to assess the effects of climate change relevancy (climate relevant vs. climate irrelevant) and sex (female vs. male) on RT. As can be seen in Fig. 2a, there was an effect of climate change relevancy, $F(1, 37) = 4.91$, $p = .03$, $\eta_p^2 = .12$, where RTs were faster on climate-relevant ($M = 365.02$, SE $= 6.31$) compared to climate-irrelevant ($M = 368.94$, SE $= 6.56$) trials. The effects of sex ($F(1, 37) = 0.79$, $p = .38$, $\eta_p^2 = .02$) and sex $\times$ climate change relevancy ($F(1, 37) = 1.30$, $p = .26$, $\eta_p^2 = .03$) were nonsignificant.

The climate change relevancy effect is consistent with an attentional bias to climate change-relevant images. That is, target detection at climate-relevant locations benefitted from participants' attention being focused at the location of the climate change-relevant image prior to target presentation. Although females tended to have a greater pro-environmental disposition relative to males (i.e., higher NEP scores), we did not observe sex differences in attentional bias to climate change images. This is consistent with meta-analytic data regarding sex differences for other types of attentional bias (Campbell and Muncer 2017) and suggests that climate images capture attention equally across males and females. The finding that climate images capture attention adds to the previous work showing that a variety of emotionally salient visual signals ranging from snakes and spiders to desirable foods and baby pictures capture attention (Brosch et al. 2007; Carlson et al. 2009). It should be noted that the magnitude of the attentional bias effect for climate change-relevant images was rather small (i.e., ~4 ms) compared to that observed with facial expressions (i.e., 5–14 ms; Torrence et al. 2017). This is likely due to the relative complexity of the climate change-relevant images used in our study. Indeed, more complex images have previously been shown to produce a relatively small threat bias (~4 ms; Carlson et al. 2009).

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[1] Note that the effect of block (or time) did not interact with the attentional bias effect, $F(2, 74) = 1.15$, $p = .32$, $\eta_p^2 = .03$. Thus, similar to previous findings, attentional bias does not appear to habituate across time (Weber et al. 2016).
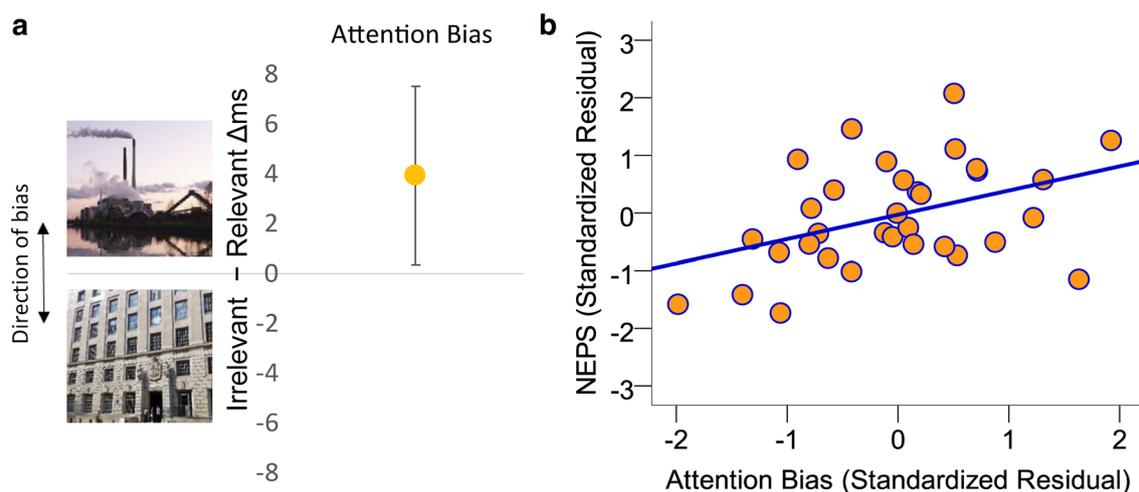
Fig. 2 **a** Reaction times were faster for climate-relevant compared to climate-irrelevant trials in the dot-probe task representing an attentional bias to climate change-relevant images. **b** After accounting for variability in sex, age, task accuracy, and reaction time, attentional bias correlates with New Ecological Paradigm (NEP) scale scores. Note that NEP scores on the *y* axis are standardized regression residuals following step 1 in the regression model

This finding also adds to previous work indicating that climate change images are emotionally salient (O'Neill and Nicholson-Cole 2009; Leviston et al. 2014; Chapman et al. 2016) by providing objective data that, similar to other emotional images, climate images produce an attentional bias. Given the incredible impact of climate change (Field et al. 2014; Smith et al. 2014), it is encouraging that climate change-relevant images capture attention. Yet, based on this finding alone, the behavioral consequences/correlates of this attention capture are unclear. It has been noted that many images of climate change represent scenes that are not immediately experienced by most viewers (e.g., a polar bear on a melting ice cap) and therefore, may not be effective means of communicating the consequences of climate change to non-expert audiences (Nicholson-Cole 2005; O'Neill and Nicholson-Cole 2009; Nerlich et al. 2010). In addition, previous research indicates that images categorized as high in negative affect are associated with elevated feelings of importance and engagement regarding the topic, yet have produced mixed findings as to whether such images motivate engagement to reduce the effects of climate change (O'Neill and Nicholson-Cole 2009; Leviston et al. 2014; Chapman et al. 2016). Regardless, our results suggest that when climate change-relevant images compete for attention with less-relevant images—a necessary prerequisite for the manifestation of attentional bias (Mathews and Mackintosh 1998)—climate change images are preferentially processed. We explore the potential behavioral significance of this prioritized processing in the following section.

Linking attentional bias to environmental orientation using hierarchical linear regression

Attentional bias scores were calculated as the climate irrelevant–climate relevant (i.e., incongruent–congruent) difference in RT. To assess the extent to which attentional bias correlates with NEP scores, we used a two-step hierarchical linear regression. Step 1 included known correlates such as participant sex and age (Dietz et al. 2002) as well as task-related control variables (i.e., average RT and accuracy).[2] In step 2, attention bias scores were entered to assess the degree to which attentional bias explained unique variability in NEP scores. Collectively, the variables included in step 1 significantly explained the variability in NEP scores. The addition of attention bias in step 2 explained variability in NEP scores above and beyond the variables included in step 1, F_{change} (1, 27) = 9.92, p = .004, R^2 change = .16 (see Table 1 for regression statistics).[3]

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[2] Mean accuracy and reaction time in the dot-probe task were positively correlated (r = .40, p = .01), and mean accuracy correlated with attention bias scores (r = .35, p = .03). Previous research has shown that mean reaction time correlates with other dispositional factors such as anxiety (Mogg et al. 2008; Zvielli et al. 2015; Aday and Carlson 2018). Therefore, these factors were included as control variables in the regression model.

[3] In an alternative regression model, we residualized age, mean RT, and accuracy on NEP scores and then used sex and attentional bias as predictors of these residualized NEP scores. This model resulted in similar effects including overall model fit (F (2, 30) = 11.27, p = .0002, R^2 = .43) as well as sex (β = .51, t = 3.68, p .001) and attention bias (β = .47, t = 3.39, p .002) as significant predictors.

Table 1 Linear model coefficients of New Ecological Paradigm scale scores

	B	SE	β	t	p
Step 1					
$F_{(4, 28)} = 4.51$, $p = .006$, $R^2 = .39$					
Constant (*y* intercept)	91.52	63.23		1.45	0.16
Sex	7.81	2.60	0.48	3.00	0.01
Age	− 0.23	0.80	− 0.04	− 0.29	0.78
Dot-probe accuracy	− 10.98	64.63	− 0.03	− 0.17	0.87
Dot-probe reaction time	− 0.08	0.03	− 0.38	− 2.27	0.03
Step 2					
$F_{(5, 27)} = 6.74$, $p = .0003$, $R^2 = .56$					
Constant (*y* intercept)	175.44	61.16		2.87	0.008
Sex	7.43	2.27	0.45	3.28	0.003
Age	− 0.92	0.73	− 0.17	− 1.26	0.22*
Dot-probe accuracy	− 82.63	60.69	− 0.22	− 1.36	0.19*
Dot-probe reaction time	− 0.08	0.03	− 0.39	− 2.71	0.01
Attention bias	0.37	0.12	0.47	3.15	0.004

*When these nonsignificant variables are excluded, the overall model remains significant ($R^2 = .51$) and attention bias remains a significant variable (R^2 change $= .12$, $p = .01$)

Hierarchical linear regression indicates that attentional bias to climate change-relevant images is related to environmental disposition (see Fig. 2b). It is important to note that the variability in environmental orientation explained by attentional bias to climate change-relevant images is distinct from the variability explained by sex and age. In addition, by including overall task RT and accuracy in step 1, the variability explained by attentional bias cannot be attributed to non-specific task performance (e.g., speed of information processing). In short, attentional bias itself explained 16% of the variance in environmental disposition and collectively all variables explained 56% of the variance.

The finding that attentional bias to climate change-relevant images is related to environmental orientation has important implications. First, this relationship adds support to our finding that climate images capture attention by providing convergent validity with another pro-environmental construct. In addition, this relationship suggests that although the average bias to climate change-relevant images was rather low (~ 4 ms), it is greater in those with a pro-environmental disposition.[4] Of broader interest are the implications of how the current finding integrates with the recent literature on attention training. In particular, with training, attentional biases can be modified and subsequently

[4] Given that our climate change-relevant images (on average) were rated higher in negative valance and arousal, future research should assess the extent to which other negative valence high arousal images capture attention in individuals with a pro-environmental disposition.

change behaviors associated with attention bias. For example, previous research has shown that experimentally inducing an attentional bias to negative or positive emotional content *causes* heightened levels of negative (Mathews and MacLeod 2002) or positive (Grafton et al. 2012) affectivity, respectively. In addition, in anxiety disorders, attention bias modification treatments are used to reduce maladaptive attentional biases and in turn reduce anxiety (Hakamata et al. 2010; Mogg et al. 2017). Given this, it is reasonable to speculate that attention bias modification training (or similar training) could be used to increase attention to climate change and in turn increase pro-environmental attitudes and behaviors. Of course, as of now, this speculation remains untested. Our lab is currently collecting data to directly assess this possibility. However, we hope that others will be encouraged by the findings presented here and further explore this relationship and its possible implications. It should be noted, that since both attentional bias and environmental attitudes were measured (rather than manipulated) in the current study, the direction of the observed relationship between attentional bias and environmental disposition is unclear. Further research is needed to determine whether attentional bias leads to increased environmental orientation or vice versa. Nevertheless, establishing the link between attentional bias and environmental disposition is a promising first step.

Conclusions

In a sample of college students, we tested the hypotheses that emotionally salient climate change-related images capture attention and that pro-environmental attitudes are associated with attentional bias to climate images. In support of these hypotheses, we present the first evidence that climate change-relevant images capture spatial attention and participants' level of attentional bias related to their environmental orientation. Collectively, these findings suggest that climate change-relevant images are salient signals—especially for those with pro-environmental attitudes.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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