Accepted for Publication in the Journal of Environmental Psychology

Word count: 10.157

Increasing People's Acceptance of Anthropogenic Climate Change with Scientific Facts: Is Mechanistic Information More Effective for Environmentalists?

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Author Note

This research was financially supported by a grant from the Helmholtz Society and the German State of Saxony-Anhalt as part of the Helmholtz Alliance ENERGY-TRANS, by grant 03SFK4Q0 from the German Federal Ministry of Education and Research (BMBF) as part of the Kopernikus Project ENavi, by the Committee on Research of the University of California, and a bequest from the estate of Professor Barbara White. None of the funding sources had any involvement in study design, collection, analysis and interpretation of data; in the writing of the report; or in the decision to submit the article for publication. We thank Heiko Lenz, Manya Teschke, and Juliane Walther for their help collecting the data, Constanze Kemmerer, Fiona Niebuhr, Baljeet Rai, Hannes Walz, and Lisa Zhang for their help coding participants' answers to the knowledge items, and Jane Zagorski for her language support.

Our research adhered to the ethical principles and the ethical code of conduct for research with human participants as stated by the American Psychological Association (2017). Participants were informed about the generic purpose (i.e., an exploration of their beliefs and everyday behavior) and the specific procedure we followed in our research. At the end of the study, participants were debriefed about the particular purpose of our research. In our paper, we report how we determined our sample size, all data exclusions, all manipulations, and all measures.

Declarations of interest: none.

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Abstract

Knowledge-deficit models highlight that providing novel information increases knowledge and acceptance of empirical facts. Motivated cognition models, however, highlight that people often discount new attitude-conflicting facts. Thereby, according to motivated cognition models, people's levels of global warming knowledge and anthropogenic climate change acceptance markedly reflect their preexisting environmental attitude. In four studies (N = 845), we tested the efficacy of new information to foster knowledge and alter acceptance while simultaneously controlling for environmental attitude. Despite corroborating the association of knowledge and acceptance (Study 1), providing information about the physical-chemical mechanism behind global warming did not always promote the acceptance of anthropogenic climate change (Study 2 vs. Studies 3 and 4). Moreover, acceptance increases induced with mechanistic information did not exceed acceptance gains induced with information about global warming's consequences (Study 3). By contrast, our findings corroborate environmental attitude's relevance for two central remnants of learning: knowledge (Studies 1, 3, and 4) and behavior (e.g., information seeking: Study 4).

Keywords: environmental attitudes, knowledge management, information dissemination, climate change communication, social acceptance

Introduction

If people only knew the physical-chemical mechanism behind global warming, they would surely more fully accept the idea that humans cause climate change. Such hopes hinge on the common expectation that people's cognitive systems of beliefs, attitudes, and knowledge readily accommodate to novel information (e.g., Anderson, 1971). Thus, providing new facts is seen as an effective means to rectify defective beliefs and unjustified attitudes to ultimately promote proper behavior (e.g., Ballantyne & Packer, 1996; Bord, O'Connor, & Fisher, 2000). In line with this so-called knowledge-deficit model (see, e.g., Sloman & Fernbach, 2017), previous research suggested that educational attainment is the single strongest determinant of climate change awareness (Lee, Markowitz, Howe, Ko, & Leiserowitz, 2015), and information about the physical-chemical origins of global warming was replicably found to increase acceptance of anthropogenic climate change (e.g., Ranney & Clark, 2016; Ranney, Shonman, Fricke, Lamprey, & Kumar, 2019; see also Joslyn & Demnitz, 2020).[1]

Interestingly, however, motivated cognition models (for an overview, see, e.g., B. T. Johnson & Eagly, 1989; Kunda, 1990) suggest that people often discount new facts that go against their attitudes and vice versa: Validating information reinforces people's preexisting attitudes (Ditto & Lopez, 1992; Pomerantz, Chaiken, & Tordesillas, 1995). In other words, when people already believe that environmental protection is imperative they are more ready to learn the physical-chemical, mechanistic explanation of global warming. Thus, these models suggest that people's acceptance of anthropogenic climate change is a substantial function of their preexisting attitudes and their susceptibility to take in mechanistic information will considerably depend on the extent to which they hold these attitudes.

In this article, we explore the two notions with a set of four studies in the realm of anthropogenic climate change beliefs. Specifically, we asked: (a) Does information about the mechanism behind global warming further people's acceptance of climate change as caused

by humans? And: (b) Does the extent to which people encode physical-chemical information about global warming depend on their preexisting environmental attitude? Notably, as the answer to both of these questions may concurrently be yes, the notions of knowledge-deficit and motivated cognition are not at odds (van der Linden et al., 2017; see also Longnecker, 2016, for an integrated model). Historically, knowledge-deficit models and motivated reasoning models have both had arguably good and complementary success. Common examples of the synergism of the two models' explained phenomena include the increasing (if sometimes nonlinear) societal acceptance of heliocentrism, evolution, germ theory, and the ills of tobacco use. Populations tend to be gradually *more* accepting of valid information over time, even while they are also often *slow* to accept that information when it conflicts with some (or most) individuals' deeply interconnected, and especially inconvenient, beliefs (e.g., for climate change: beliefs involving nationalism, evolution, creation, higher power(s), and the afterlife; see Ranney et al., 2019, on Reinforced Theistic Manifest Destiny theory).

Notwithstanding, if information about the mechanism behind global warming were more effective for environmentalists, the potential benefit of environmental education programs providing such information would be limited and leave others behind. In the following, we will present the existing evidence on whether and how beliefs in anthropogenic climate change can be changed and outline our research goals.

Mechanistic Explanations Increase Acceptance

Knowledge about environmental issues has been found to correlate with acceptance of anthropogenic climate change (e.g., Ranney & Clark, 2016; Reser, Bradley, Glendon, Ellul, & Callaghan, 2012; Stevenson, Peterson, Bondell, Moore, & Carrier, 2014), and *mechanistic* physical-chemical explanations of global warming in particular are believed to open people's minds and ultimately convince them of the scientific consensus that climate change is human-made (see, e.g., Bunten & Arvizu, 2013; Ranney et al., 2019; Shtulman & Harrington, 2016; Sloman & Fernbach, 2017).

Laypeople's understanding of the mechanism behind global warming (i.e., their mechanistic global warming knowledge) generally seems to be rather limited. Ranney and Clark (2016) reported that virtually none of their U.S. participants knew the basic physical-chemical explanation of global warming. Similarly, Tobler, Visschers, and Siegrist (2012) found that more than one third of their Swiss respondents *incorrectly* identified the ozone hole as the main cause of the greenhouse effect and were unaware that greenhouse gases partly retain the Earth's heat.

Presenting the scientifically accepted, greenhouse-gas-related explanation of global warming is thus believed to prompt a reappraisal of the issue (see, e.g., Bunten & Arvizu, 2013; Lombardi, Sinatra, & Nussbaum, 2013; Ranney, Munnich, & Lamprey, 2016). In the wake of novel information, alternative explanations (e.g., increased solar irradiation or stratospheric ozone depletion) expectedly appeared—by comparison—implausible or unlikely. Correspondingly, mechanistic explanations were found to weaken preexisting contradictory views (Fernbach, Rogers, Fox, & Sloman, 2013). A focus on the quality of a mechanistic explanation was also found to significantly reduce the appeal of weak explanations—even for climate skeptics (D. R. Johnson, 2017; see also Lombardi et al., 2013). In their research, Ranney and Clark (2016; see also Ranney et al., 2019) greatly reduced their participants' knowledge deficit with a brief (i.e., 2 to 10 min) explanation of the physical-chemical processes behind global warming. These gains in knowledge were accompanied by a more pronounced acceptance of anthropogenic climate change. Increases in both knowledge and acceptance were durable, as they remained statistically significant up to a 5-week posttest. These findings have since been replicated by an unrelated laboratory (Joslyn & Demnitz, 2020) who showed that a mechanistic explanation (adapted from Ranney & Clark, 2016) increased the amount participants would contribute to a climate change cause. Notably, the largest effect was seen among conservatives, opposite to what one may expect if motivated reasoning were operating.

Research on the effects of information on anthropogenic climate change acceptance has not yet controlled for participants' preexisting environmental attitude as a potential moderator (see, e.g., Geiger, Swim, & Fraser, 2017; D. R. Johnson, 2017; Lombardi et al., 2013; Simon, Volmert, Bunten, & Kendall-Taylor, 2014). As we explain next, however, it is rather reasonable to assume that two central remnants of learning—knowledge and behavior (here: expressing acceptance of anthropogenic climate change)—depend on people's environmental attitude.

Attitude Controls Learning and its Remnants, Knowledge, and Behavior

Environmentalists (i.e., people who aim to protect the environment and, thus, the climate) are typically expected to engage in a set of activities that reflect their attitude levels. For instance, they may publicly acknowledge that climate change is human-caused, vote for representatives with a known pro-environmental record, recycle cardboard regularly, and avoid foods that are particularly environmentally harmful (e.g., meat). Generally, a person's esteem for an attitudinal "object" (e.g., environmental or climate protection) or goal (e.g., preserving the environment, mitigating climate change) becomes obvious in the extent to which she or he engages in increasingly costly behaviors that involve increasingly demanding barriers or progressively more painful sacrifices (Kaiser, Byrka, & Hartig, 2010; Kaiser & Wilson, 2019). Expectedly, people's environmental attitude has repeatedly been found to be a reliable predictor of environmentally protective engagement (see Bamberg & Möser, 2007, for an overview).

As learning involves behavior (e.g., reading and searching for information), it would have been surprising to find core remnants of learning (i.e., knowledge and acceptance) to be impervious to differences in people's attitude levels. Both general environmental knowledge and specific energy-related knowledge were found to correlate positively with people's propensity to protect the environment (i.e., their environmental attitude; Arcury, 1990; Frick, Kaiser, & Wilson, 2004). Environmental attitude also significantly explained (a) the

expectation that the Earth's temperature will increase, (b) intentions to help mitigate climate change, (c) support for respective governmental initiatives (Bord et al., 2000), and (d) perceived threat from and the importance of global warming (Whitmarsh, 2008).

Such findings may indicate biased information processing. Motivated cognition models suggest that people's beliefs are shaped not only by the information they receive but also by what they *prefer* to believe (e.g., B. T. Johnson & Eagly, 1989; Kahneman & Tversky, 1996; Kunda, 1990). For instance, more extreme attitude levels were found to trigger selective elaborations and, ultimately, selective judgments (e.g., Pomerantz et al., 1995). Likewise, people were found to question the validity of information that contradicted their attitudes by generating more alternative explanations for such unwelcome information and by selectively exposing themselves to attitude-confirming information (e.g., Ditto & Lopez, 1992; Hart et al., 2009). Applied to people's acceptance of anthropogenic climate change, these models suggest that people will discount the physical-chemical mechanistic explanation if it goes against their attitude. Indeed, motivated cognition has been referred to as the primary explanation for the limited effectiveness of efforts to correct misperceptions about climate change (Benegal & Scruggs, 2018; Kahan, Jenkins-Smith, & Braman, 2011). Vice versa, if the information provided is in line with an already pronounced inclination for climate protection, it will reinforce this preexisting attitude and strengthen people's acceptance of anthropogenic climate change. Some authors have correspondingly reported effects of providing information that they claim to be polarizing (Kahan et al., 2011; but see van der Linden et al., 2017). In summary, motivated cognition models predict that both mechanistic global warming knowledge and acceptance of anthropogenic climate change are related to people's preexisting environmental attitude. Increases in people's knowledge and acceptance of anthropogenic climate change induced by providing mechanistic information may correspondingly be moderated by their preexisting attitude.

Research Goals

In a series of four studies, we aimed to test whether acceptance of anthropogenic climate change can be increased by providing state-of-the-art scientific information about the physical-chemical mechanism presumed to lie behind global warming and whether understanding the mechanism behind global warming and accepting that climate change is human-caused depends on people's preexisting environmental attitude levels. In Study 1, we explored whether participants' environmental attitude could, in principle, account for the bivariate correlation between people's global warming knowledge and their acceptance of anthropogenic climate change. In Study 2, we tested experimentally how a brief (i.e., 400-word) text presenting the mechanistic explanation of global warming affected participants' acceptance of anthropogenic climate change. In Study 3, we changed the format in which the information was presented to video messages. In both experiments, we controlled for participants' preexisting environmental attitude. In the final, fourth study, we tested experimentally whether actively and voluntarily seeking more mechanistic information about global warming is related to participants' preexisting environmental attitude.

Study 1

This study provided a simple cross-sectional test of the partial correlation of mechanistic global warming knowledge and acceptance of anthropogenic climate change while controlling for participants' environmental attitude.

Method

Participants. Previous research indicated a correlation of $r = .22$ between knowledge and acceptance (Ranney & Clark, 2016, Study 1). To detect a correlation of that size with a power of $1 - \beta = .90$, G*Power (Faul, Erdfelder, Buchner, & Lang, 2009) indicated that a sample size of $N = 209$ is necessary for a two-tailed test with $\alpha = .05$. To account for potential dropouts, we recruited a convenience sample of $N = 220$ participants through social networks (e.g., Facebook), mailing lists and news groups[2] of which $N = 181$ answered the items

pertaining to our three core constructs (i.e., environmental attitude, mechanistic knowledge, and acceptance of anthropogenic climate change). Using the software *plagscan.com*, we excluded two participants for copying the answers to the knowledge questions verbatim from the Internet.[3] These exclusions left us with a final sample of $N = 179$ (age: $M = 34.68$, $SD = 14.24$; 51% women; 34% men; 84% indicating German was their first language versus 3% indicating that it was not).

Procedure. Participants completed the task online at a location of their convenience. A lottery for three vouchers for an online retailer (50 € in total) was offered as an incentive for participation. Participants first filled out the attitude measure, next answered the knowledge questions and indicated the extent to which they accepted anthropogenic climate change, and finally completed a list of sociodemographic descriptors.

Environmental attitude. Participants' attitude levels were estimated based on 67 items adopted from Kaiser and Wilson (2004) and Kaiser, Schultz, and Scheuthle (2007). Different, overlapping item sets were employed in our four studies (see the online appendix for details: https://osf.io/xeu67/). Items referred to either participants' engagement in environmentally protective behavior (e.g., "I reuse my shopping bags") or their respective intentions (e.g., "I intend to refrain from driving my car in or into the city").[4] Items that represented unecological activities were reverse-coded (e.g., "I kill insects with a chemical insecticide"). Items that were assessed on a polytomous scale (ranging from 1 = *never* to 5 = *always*; and from 1 = *undecided* to 5 = *decided* for self-reported behavior and intentions, respectively) were dichotomized to suppress excessive measurement error and to match the format of the remaining *yes/no* items (Kaiser & Wilson, 2004). Specifically, we collapsed 1-3 to indicate a low attitude level, and 4-5 to indicate a high attitude level. When participants were unable to answer an item (e.g., asking about driving behavior when people did not have a license), they could mark *not applicable*, which was treated as a missing value. After theses preparatory recodings, we jointly calibrated all 67 items using the dichotomous Rasch model (for

technical details, see Rasch, 1960/1980; for a similar approach, see Kaiser, Merten, & Wetzel, 2018; for its theoretical grounding, see Kaiser & Wilson, 2019). Individual environmental attitude scores were derived with a maximum likelihood approach and estimated as logits (i.e., the natural logarithm of a person's engagement/nonengagement ratio). Larger logit values reflected a more pronounced attitude. Across all four studies, the (separation) reliability of our attitude measure was reasonable (*rel.* = .76).

Mechanistic knowledge. Participants' mechanistic global warming knowledge was assessed with three short-answer questions adapted from Ranney and Clark (2016). Research assistants rated participants' answers on three central concepts: (a) differentiation of light entering and exiting the atmosphere, (b) atmospheric greenhouse gases' interactions with radiation, and (c) the increased atmospheric retention time of energy, each contributing three points toward a maximum of nine points. Two different raters provided independent scores. In line with previous applications of the scoring rubric (for details, see Ranney & Clark, 2016, Appendix S3), interrater reliability was reasonable (Cohen's $\kappa = .78$). The average of the two scores served as the final global warming knowledge score.

Acceptance of anthropogenic climate change. Participants' acceptance of anthropogenic climate change was assessed with a sum score of seven evaluative statements adapted from Ranney and Clark (2016). Example items are "Human activities are largely responsible for climate change (global warming)" and "I am certain that global warming (an increase in Earth's average temperature) is actually happening" (ranging from 1 = *extremely disagree* to 9 = *extremely agree*).[5] The reliability of the scale was reasonable ($\alpha = .86$).

Results and Discussion

Replicating previous U.S.-based findings (Ranney & Clark, 2016), participants' acceptance of anthropogenic climate change (see Table 1 for means and standard deviations) was correlated with their mechanistic global warming knowledge, $r = .35$, $p < .001$. In line with our predictions, both acceptance and knowledge were correlated with participants'

environmental attitude, $r = .49$, $p < .001$, and $r = .21$, $p = .006$, respectively. The partial correlation between mechanistic knowledge and acceptance of anthropogenic climate change, controlling for environmental attitude, remained substantial and significant, $r_p = .29$, $p < .001$, suggesting that environmental attitude can only account for the bivariate association between people's global warming knowledge and their acceptance of anthropogenic climate change in part. In other words, Study 1's results can be interpreted as partial support for the knowledge deficit model, suggesting that participants who had acquired an adequate understanding of global warming's mechanism in the past may in turn have developed a stronger acceptance of its anthropogenic origin. However, the current research only considered one out of many potential covariates, environmental attitude. Other covariates such as intelligence or openness to experience may, of course, also (i.e., in addition to environmental attitude) account for the remaining association between knowledge and acceptance (see Fiedler, Harris, & Schott, 2018). Even so, as past work has shown information-driven acceptance gains even after substantial delays for post-testing (up to 34 days; Ranney & Clark, 2016), it is unclear how such covariates would act so distally in the future so as to obviate the notion that the information caused the longevities of the gains.

In Studies 2 and 3, we employed an experimental test of our research question of whether acceptance of anthropogenic climate change can be increased by providing state-of-the-art scientific information about the physical-chemical mechanism presumed to lie behind global warming and whether such learning effects are moderated by people's preexisting environmental attitude.

Study 2

This study tested how a brief (i.e., 400-word) passage on the physical-chemical mechanism behind global warming affected participants' acceptance of anthropogenic climate change. To this end, we contrasted a group that received Ranney and Clark's (2016) original explanation with a control group receiving information that was unrelated to global warming.

Moreover, as field research conducted in museums often draws on allegorical explanations to foster people's environmental knowledge (see, e.g., Bunten & Arvizu, 2013), we provided a third group of participants with an allegorical version of the original material (see https://osf.io/xeu67/ for all interventions employed in this research). This explanation used the *greenhouse allegory*; it did not differentiate between wavelengths of incoming and outgoing light, nor did it refer to any chemical details (or even the term "greenhouse gases"). We also tested the effect that people's preexisting environmental attitude had on their mechanistic knowledge and acceptance of anthropogenic climate change. Notably, the knowledge-deficit model suggests that both the original and the allegorical explanations possess the potential to increase knowledge and acceptance of anthropogenic climate change. By contrast, motivated cognition models suggest that both knowledge and acceptance are a function of participants' preexisting attitude and that this attitude moderates any increases in knowledge and acceptance induced by the information about how global warming works.

Method

Participants. We recruited a convenience sample of $N = 222$ participants through social networks, mailing lists and news groups[2]. We did not conduct an a priori power analysis for Study 2. Rather, data collection was scheduled to conclude after 2 weeks. In total, $N = 180$ participants answered the items pertaining to our three core constructs (i.e., environmental attitude, mechanistic knowledge, and acceptance of anthropogenic climate change). As in Study 1, two participants who had copied their answers to the knowledge questions verbatim from the Internet were excluded from all analyses.[3] These exclusions left us with a final sample of $N = 178$ (age: $M = 28.75$, $SD = 10.00$; 59% women; 40% men; 97% indicating German was their first language versus 3% indicating that it was not). A post hoc power analysis using G*Power (Faul et al., 2009) indicated that—assuming a medium effect size of $f = 0.25$ (equivalent to $\eta_p^2 = .06$)—our sample size provided a power of $1 - \beta = .80$ for an ANCOVA with $\alpha = .05$, comparing the three experimental groups and controlling for

environmental attitude. Participants in the three conditions did not differ significantly on age, gender, or environmental attitude ($.08 \leq p \leq .85$), and thus, randomization was generally successful.

Procedure. Participants completed the task online at a location of their convenience. A lottery for eight vouchers to an online retailer (600 € in total) was offered as an incentive for participation. All participants first completed a list of sociodemographic descriptors and the environmental attitude measure. Next, we randomly allocated participants to one of three conditions. They were asked to read a text that, in two conditions, explained the mechanism behind climate change (i.e., original and allegorical climate information), and in a third condition described research on communication (i.e., control condition). Then, all participants answered the global warming knowledge questions and indicated their acceptance of anthropogenic climate change.[5,6] Again, the interrater reliability of the global warming knowledge scores and the internal consistency of the acceptance of anthropogenic climate change items were acceptable ($\kappa = .77$ and $\alpha = .73$, respectively).

Results and Discussion

To check the effectiveness of our information, we compared postintervention mechanistic knowledge scores between conditions, $F(2, 175) = 16.32$, $p < .001$, $R^2 = .16$. The experimental conditions were dummy coded to reflect the additional knowledge provided by Ranney and Clark's (2016) original climate information and the allegorical version, respectively, in comparison with the control condition. Expectedly, the knowledge scores of participants receiving the original climate information ($n = 69$, $M = 4.57$, $SD = 3.04$, 95% CI [3.83, 5.30]) and those receiving the allegorical information ($n = 54$, $M = 3.38$, $SD = 1.65$, 95% CI [2.93, 3.84]) significantly exceeded the scores of the control group ($n = 55$, $M = 2.17$, $SD = 1.77$, 95% CI [1.69, 2.66]), $t(175) = 5.70$, $p < .001$, $\eta_p^2 = .16$ and $t(175) = 2.73$, $p = .007$, $\eta_p^2 = .04$, respectively. Hence, the two ways of imparting information were successful in raising participants' knowledge (see Figure 1, left panel). Additionally controlling for

participants' preexisting environmental attitude did not change this pattern of results, and environmental attitude did not predict participants' postintervention knowledge levels, $t(174) = 1.47$, $p = .14$, $\eta_p^2 = .01$. Environmental attitude also did not moderate the effects of providing the mechanistic explanation, neither in its original nor in the allegorical form, $t(172) = 0.77$, $p = .44$, $\eta_p^2 < .01$ and $t(172) = 0.27$, $p = .79$, $\eta_p^2 < .01$, respectively (see Table 1 for bivariate associations).

We next used acceptance of anthropogenic climate change as the dependent variable. Contrary to our expectations, we found no significant differences between groups, $F(2, 175) = 0.11$, $p = .90$, $R^2 < .01$. Specifically, neither the acceptance levels of participants receiving the original climate information ($M = 7.00$, $SD = 0.90$, 95% CI [6.78, 7.22]) nor the levels of those receiving the allegorical climate information ($M = 7.05$, $SD = 1.02$, 95% CI [6.77, 7.33]) significantly surpassed the acceptance reported by the control group ($M = 6.97$, $SD = 0.97$, 95% CI [6.70, 7.23]), $t(175) = 0.20$, $p = .84$, $\eta_p^2 < .01$ and $t(175) = 0.46$, $p = .65$, $\eta_p^2 < .01$, respectively (see Figure 1, right panel). This pattern of results did not change when we controlled for participants' preexisting environmental attitude. Once more, attitude also did not significantly moderate the effect of the original or allegorical climate information, $t(172) = 0.00$, $p = .99$, $\eta_p^2 < .01$ and $t(172) = 0.25$, $p = .80$, $\eta_p^2 < .01$, but it did emerge as a significant predictor of participants' postintervention acceptance levels, $t(174) = 4.38$, $p < .001$, $\eta_p^2 = .10$.

In summary, although we have found significant between-group differences in post-intervention knowledge, no such differences could be found in acceptance of anthropogenic climate change. Contrary to the knowledge-deficit model's propositions and contrary to various previous findings (Ranney & Clark, 2016; Ranney et al., 2019; see also Joslyn & Demnitz, 2020), providing mechanistic information filled the knowledge deficit, but this new knowledge was apparently insufficient to raise participants' acceptance—no matter whether environmental attitude was controlled for or not (see General Discussion for methodological

and theoretical considerations). As we found no indication of preexisting attitudes moderating (i.e., conditioning) the effects of the two types of information, motivated cognition also must not be held responsible for any gains in knowledge or acceptance. In other words, we found no indication of people's positions moving further apart through the provision of information (as indicated by Kahan et al., 2011; but see e.g. Ranney & Clark, 2016 for contrasting evidence). Remarkably, however, (postintervention) acceptance turned out to be significantly associated with participants' preexisting attitude levels.

Study 3

In a conceptual replication of Study 2, we changed the format in which the information was presented. This time, we tested the effect of a 4-min video that provided the mechanistic climate information, again controlling for participants' preexisting environmental attitude. To increase statistical power and to capture actual gains in acceptance, we tested for within-participant effects on acceptance (i.e., with a pre-post design). Moreover, we contrasted the effect of the mechanistic information (presented in a video) against both a control group that did not watch any video and a third group that watched a video that listed the *consequences* of climate change in Germany and Bangladesh, without discussing the mechanism (henceforth called the consequences video; see https://osf.io/xeu67/ for all interventions employed in this research).

Multiple scholars have argued that environmental education campaigns will be particularly successful in promoting people's acceptance of anthropogenic climate change if they can foster people's understanding of the underlying mechanism—rather than relying on information about the environmental problem alone (see, e.g., Sloman & Fernbach, 2017). The knowledge-deficit model thus suggests that participants watching the mechanistic instructional video would exceed the other two groups in terms of increases in participants' acceptance of anthropogenic climate change. Once again, we also tested for effects of motivated cognition via the potential interaction of the two climate-related videos' effects

with people's environmental attitude on both knowledge and acceptance. And finally, we again explored the effect of people's preexisting environmental attitude on their mechanistic knowledge and their acceptance of anthropogenic climate change.

Method

Participants. For our core test of the between-group differences in acceptance, controlling for environmental attitude, we assumed a medium effect size of $f = 0.25$ (equivalent to $\eta_p^2 = .06$). For an ANCOVA with $\alpha = .05$, G*Power (Faul et al., 2009) indicated that a sample size of $N = 231$ would be necessary to obtain a power of $1 - \beta = .90$. Because we had observed substantial dropout rates in Studies 1 and 2, we screened our sample for dropouts and decided to stop collecting data after $N = 223$ participants (recruited through social networks, mailing lists and news groups[2]) had answered the items pertaining to our three core constructs. Four participants who had copied answers to the knowledge questions verbatim from the Internet were excluded from all analyses.[3] These exclusions left us with a final sample of $N = 219$ (age: $M = 26.16$, $SD = 9.41$; 69% women; 31% men; 96% indicating German was their first language versus 4% indicating that it was not). Participants in the three conditions did not differ significantly on age, gender, environmental attitude, pretest acceptance, or pretest self-rated climate change knowledge ($.40 \leq p \leq .98$).

Procedure. Participants completed the task online at a location of their convenience. A lottery for three vouchers to an online retailer (45 € in total) and course credit for psychology students ($n = 44$) were offered as incentives for participation. The procedure largely corresponded with Study 2, but we added a baseline assessment of participants' acceptance of anthropogenic climate change to enable within-participant tests.[5,6] Again, the reliability and consistency indicators of global warming knowledge and of acceptance of anthropogenic climate change (separate pre- and postintervention scores) were acceptable ($\kappa = .88$, $\alpha = .83$ and $\alpha = .86$, respectively).

Results and Discussion

To check the effectiveness of our mechanistic information, we again compared postintervention mechanistic knowledge scores between conditions, $F(2, 216) = 52.19$, $p < .001$, $R^2 = .33$. Experimental conditions were dummy coded to reflect the additional knowledge provided by Ranney and Clark's (2016) mechanistic climate change information and the consequences video, respectively, in comparison with the control condition. Expectedly, knowledge scores of participants receiving the mechanistic climate information ($n = 71$, $M = 6.09$, $SD = 2.61$, 95% CI [5.47, 6.71]) significantly exceeded the knowledge scores obtained in the control group ($n = 67$, $M = 2.37$, $SD = 2.15$, 95% CI [1.84, 2.89]), $t(216) = 9.34$, $p < .001$, $\eta_p^2 = .29$. Hence, the video presenting the mechanistic information was apparently successful. Also in line with our expectations, we found no evidence for increased mechanistic knowledge induced by the consequences video because the knowledge scores of participants watching that video ($n = 81$, $M = 2.93$, $SD = 2.24$, 95% CI [2.43, 3.42]) did not significantly exceed the control group's knowledge scores ($M = 2.37$, $SD = 2.15$, 95% CI [1.84, 2.89]), $t(216) = 1.45$, $p = .15$, $\eta_p^2 = .01$ (see Figure 2, left panel). Additionally controlling for environmental attitude did not alter the pattern of results, but it did reveal the expected main effect of participants' preexisting environmental attitude on their postintervention knowledge levels, $t(215) = 3.09$, $p = .002$, $\eta_p^2 = .04$. In line with Study 2, environmental attitude once more did not moderate the learning effect induced by the mechanistic video or the consequences video, $t(213) = 0.62$, $p = .54$, $\eta_p^2 < .01$ and $t(213) = 0.23$, $p = .82$, $\eta_p^2 < .01$, respectively (see Table 1 for bivariate associations).

We next computed a repeated-measures ANOVA with participants' acceptance as the dependent variable, time (pre- vs. postintervention) as a within factor, and experimental condition as a between factor. Contrary to our expectations, the significant main effect of time of assessment, $t(216) = 3.27$, $p < .001$, $\eta_p^2 = .05$, was not qualified by a significant interaction, $t(216) = 1.30$, $p = .19$, $\eta_p^2 = .02$, suggesting that the experimental conditions did not differ in

their extent of pre-post-intervention change in people's acceptance. We found that acceptance increased significantly in participants watching the mechanistic information video (ΔM = .20, SD = .63, 95% CI [0.05, 0.35]), $t(216) = 2.56$, $p = .01$, $\eta_p^2 = .03$, however, it also increased in participants watching the consequences video (ΔM = .21, SD = .66, 95% CI [0.06, 0.36]), $t(216) = 2.87$, $p = .01$, $\eta_p^2 = .04$. No change in acceptance was observed for the control group (ΔM = .03, SD = .68, 95% CI [-0.14, 0.20]), $t(216) = 0.35$, $p = .73$, $\eta_p^2 < .01$ (see Figure 2, right panel). This pattern of results did not change when we controlled for participants' environmental attitude. Again, attitude emerged as a significant (between-subjects) predictor of acceptance, $t(215) = 5.53$, $p < .001$, $\eta_p^2 = .13$, but not of (within-subjects) changes in acceptance, $t(215) = 0.85$, $p = .39$, $\eta_p^2 < .01$.

In summary, although we observed increases in acceptance for participants viewing the mechanistic information video, acceptance also increased for participants watching a video that focused on the consequences of climate change. These results could imply, as has been found (Ranney & Clark, 2016; Ranney et al., 2019; Velautham & Ranney, 2020; Velautham, Ranney, & Brow, 2019), that different types of environmental knowledge can fuel people's acceptance of anthropogenic climate change. In the face of extensive and increasing media coverage of climate change's consequences, some readers may question that there was a knowledge deficit to be filled with the consequences video. However, as we did not assess participants' knowledge of climate change's *consequences*, we cannot provide an empirical test for this interpretation of Study 3's findings (but see, e.g., Sloman & Fernbach, 2017 for a theoretical account).

Alternatively, the results could also reflect demand characteristics (Orne, 1962). Whereas only the mechanistic video explained global warming's physical-chemical mechanism, both videos clearly conveyed the message that global warming is occurring and human activities are largely responsible for climate change. As such, some participants may have indicated increased acceptance in an attempt to confirm the experimenters' (assumed)

hypotheses or to communicate agreement with the experimenters' (assumed) view (see General Discussion for an extended discussion).

Because the two videos differed in multiple respects in terms of both style and substance—in addition to one describing the mechanism and the other one not doing so—it is impossible for us to discern which features specifically drove the pre-to-post effects in acceptance of anthropogenic climate change in the consequences video group. Nevertheless, understanding the mechanism behind global warming was apparently not necessary for accepting its human cause (see Figure 2). We therefore no longer focused on attempting to experimentally induce learning effects and instead turned to participants' *willingness to learn* in Study 4. Specifically, we tested whether actively and voluntarily seeking more mechanistic information about global warming is a function of the extent of people's preexisting propensity or inclination to protect the environment (i.e., people's preexisting environmental attitude). Across a range of various attitude domains, previous research has demonstrated a general inclination to selectively expose oneself to attitude-confirming information (for an overview, see Hart et al., 2009). Accordingly, we expected that environmental attitude would explain a preference for longer global warming explanation videos.

Study 4

A reoccurring finding across the different samples in Studies 1 to 3 was that baseline environmental attitude predicted both knowledge (Studies 1 and 3) and acceptance (Studies 1 to 3). In Study 4, we sought to provide an explanation for these effects and predicted that environmental attitude would be the motivating force behind people's willingness to learn about anthropogenic global warming in a free-choice education setting.

Specifically, we expected that participants with higher levels of environmental attitude would spend more time watching mechanism-explaining climate change videos. People's environmental attitudes and environmental knowledge have been found to be both elevated and connected after they had dedicated their professional lives to the environmental sciences

(see Kaiser & Frick, 2002). Other previous findings suggest that environmentally inclined people are more likely to use electricity monitors that can help them understand and reduce household power consumption (Wallenborn, Orsini, & Vanhaverbeke, 2011) and are more likely to sign up for free-choice environmental education programs (Storksdieck, Ellenbogen, & Heimlich, 2005).

In contrast to our prescribed exposure to environmental information in Studies 2 and 3, real-world environmental education will typically have to rely on people's free choice to voluntarily expose themselves to information that is offered. In Study 4, we therefore explored whether the effect of environmental attitude would be evident regardless of how much the context favored such exposure by preselecting either the most inclusive informational video, or no video. Preselected (i.e., default) options are often favored by decision makers because they are interpreted as recommendations that are complied with to avoid social stigma (McKenzie-Mohr, Liersch, & Finkelstein, 2006). We therefore predicted that participants would watch longer videos when the most inclusive informational video was preselected.

Method

Participants. For our core test of the effect of environmental attitude on the length of the selected video, controlling for how much the decision context facilitated the watching of longer videos, we again assumed a medium effect size of $f = 0.25$ (equivalent to $\eta_p^2 = .06$) but this time aimed for higher power ($1 - \beta = .95$). For an ANCOVA with $\alpha = .05$, G*Power (Faul et al., 2009) indicated that a sample size of $N = 251$ was necessary. In order to account for potential dropouts, we recruited a convenience sample of $N = 333$ participants. Notably, and in contrast to Studies 1-3, we recruited U.S. participants through *Amazon Mechanical Turk* (see, e.g., Crump, McDonnell, & Gureckis, 2013). In total, $N = 295$ participants answered the items pertaining to our three core constructs. However, we excluded those who had copied their answers to the knowledge questions verbatim from the Internet ($n = 9$), those who

indicated that their computers would not play videos (n = 11), and three participants who indicated that they did not believe they would actually be watching a video. Due to previous reports of Mechanical Turk participants being somewhat inattentive to experimental instructions (e.g., Crump et al., 2013), we kept Study 4's participants under particularly close scrutiny and additionally excluded participants who failed to provide correct answers to quality control items (n = 3; see Meade & Craig, 2012).[3] These exclusions left us with a final sample of N = 269 (age: M = 33.12, SD = 12.06; 51% women; 48% men; 95% indicating they were born in the U.S. versus 4% indicating that they were not). Participants in the two default conditions did not differ significantly on age, gender, pretest environmental attitude, pretest acceptance, or both self-rated and coded climate change knowledge ($.19 \leq p \leq .95$).

Procedure. Participants completed the task online at a location of their convenience. Compensation of $0.75 (USD) was offered as an incentive for participation. We randomly allocated participants to one of eight conditions in a 2 (preselection: 5-min default vs. no-video default) x 4 (pretest: no pretest, attitude/acceptance-only pretest, knowledge-only pretest, attitude/acceptance-and-knowledge pretest) design. All participants were invited to watch one of five videos explaining the mechanism of global warming (with a running time of roughly 1, 2, 3, 4, and 5 min, respectively; see https://www.howglobalwarmingworks.org/). Alternatively, participants could also opt to watch no video (in this case, we registered 0 min). Depending on the experimental condition, the decision context either facilitated (i.e., 5-min default) or hindered (i.e., no-video default) selecting longer instructional videos (see Figure 3). After watching the instructional video (or choosing to watch no video), all participants filled out a posttest that assessed mechanistic knowledge, environmental attitude, and acceptance of anthropogenic climate change,[5] all of which allowed replications of the results of Studies 1 to 3. Finally, participants completed a list of demographic items.

In addition, participants in the *attitude/acceptance-only pretest* condition filled out the attitude and acceptance measures before selecting the video, participants in the *knowledge-*

only pretest condition answered a knowledge measure, and participants in the *attitude/acceptance-and-knowledge pretest* condition received a pretest containing attitude, acceptance, and knowledge measures. The different pretest groups thus allowed us to control for normative pressure to select longer videos triggered by the pretest measurement. As in Studies 1 to 3, the internal consistency of the acceptance items was acceptable ($\alpha = .89$ and $\alpha = .91$, for pre- and postintervention respectively). Interrater reliability of mechanistic knowledge scores was not assessed in Study 4, as it has been well established in Studies 1-3 and elsewhere (Ranney & Clark, 2016).

Results and Discussion

Neither the pretest condition nor the pretest-by-default interaction significantly predicted participants' selection of the video ($p = .74$ and .21, respectively). Accordingly, and in line with Ranney and Clark (2016), we found no evidence of a normative pressure effect induced by the pretest. We hencefore decided to collapse data across the different pretest conditions (i.e., no pretest, attitude/acceptance-only pretest, knowledge-only pretest, attitude/acceptance-and-knowledge pretest) for subsequent analyses.

Replicating Study 1's results, we found that posttest acceptance of anthropogenic climate change correlated with mechanistic global warming knowledge, $r = .25$, $p < .001$ (similar to the pretest correlation's magnitude; see Table 1 for means, standard deviations and bivariate associations). Both pre- and posttest environmental attitude could again only partially account for this association as it remained substantial and significant, $r_p = .23$, $p = .009$ and $r_p = .21$, $p < .001$, respectively. Replicating the results of Studies 2 and 3, as well as Ranney and colleagues (2019), greater pre-to-posttest increases in mechanistic knowledge were found with longer (and generally increasingly comprehensive) interventions, $r = .59$, $p < .001$ (note again that a video length of 0 minutes was registered for participants choosing not to watch any video). However, the corresponding correlation of increases in participants' acceptance of anthropogenic climate change and the length of the video was weak and did not

quite reach significance, $r = .15$, $p = .08$. As Figure 4 shows, participants' acceptance increased descriptively from pre- to posttest with all five videos—and for participants choosing to watch no video—with the longest, 5-minute mechanistic video providing a significant increase, $p = .01$ (all other $p > .14$). Thus, our expectation that increases in knowledge obtained by watching the videos would—in line with the knowledge-deficit model—spur acceptance was partially supported by the data.

To test Study 4's core hypothesis—that environmental attitude affects people's decisions to actively expose themselves to the mechanistic information regardless of how much such exposure is facilitated by the decision context—we computed an ANCOVA, $F(2, 134) = 4.11$, $p = .02$, $R^2 = .06$. As environmental attitude levels at pretest were not assessed in the knowledge-only and no-pretest conditions, 132 participants (49%) were missing by design in this analysis. In line with our expectations, our preselecting the longest video (i.e., the 5-min default) significantly facilitated information seeking about climate change's mechanism (as compared to the no-video default). Specifically, whether or not they watched them, participants assigned to the 5-min default conditions ($n = 67$) selected longer videos ($M = 2.12$ min., $SD = 1.89$ min., 95% CI [1.48, 2.06]) than participants assigned to the no-video default conditions ($n = 70$; $M = 1.77$ min., $SD = 1.69$ min., 95% CI [1.80, 2.45]; with these means including zero minutes for those choosing none), $t(134) = 2.24$, $p = .03$, $\eta_p^2 = .04$. Participants in the 5-min default conditions were almost twice as likely to select the 5-minute video for viewing. Also, participants' environmental attitude levels had a marginally significant positive effect on the length of the selected video, $t(134) = 1.84$, $p = .07$, $\eta_p^2 = .03$. There was no evidence that the decision context (i.e. 5-min default vs. no-video default) moderated this main effect of environmental attitude, as additionally controlling for the interaction term did not significantly increase the explained variance, $t(133) = 1.24$, $p = .22$, $\eta_p^2 = .01$.

In summary, Study 4 again did not provide full-throated support for the knowledge-deficit assumption. However, it did corroborate our expectation that environmental attitude

helps fuel people's readiness to expose themselves to information and, thus, to learn about climate change (i.e., their selective exposure to attitude-confirming information; Hart et al., 2009). Apparently, preexisting environmental attitude factors into the decision to actively and voluntarily seek mechanistic knowledge by watching longer videos. Nevertheless, the rather modest amount of variance explained by our model suggests that other predictors need to be considered for a more comprehensive understanding of the specific decision.

Notably, environmental attitude's main effect was not qualified by a significant interaction with how much the decision context facilitated the choosing of longer videos. This has important implications for environmental education programs that cannot rely on imposing mechanistic information on their target audiences, as we will discuss in greater detail below along with other central implications of the presented research.

General Discussion

Environmental education is not an end in and of itself. By furthering people's knowledge about environmental issues, researchers and practitioners alike aim to increase people's environmentally protective engagement (e.g., Geiger et al., 2017), their connectedness with nature (e.g., Liefländer, 2013), or at least their verbal acceptance of anthropogenic climate change (e.g., Ranney & Clark, 2016). In our research, we set out to explore whether new information about the mechanism behind global warming could be employed to increase people's acceptance that climate change is caused by humans or whether such information would reach people as a function of their preexisting environmental attitudes. Our findings obtained from both correlational and experimental research conducted in Germany and the U.S. suggest that participants learned to understand the physical-chemical mechanism behind global warming when we asked them to do so. At the same time, learning was not moderated by people's environmental attitude in our experiments. New mechanistic knowledge was, however, neither always sufficient (Study 2) nor necessary (Study 3) to further participants' acceptance of anthropogenic climate change (for alternative findings see

Joslyn & Demnitz, 2020; Ranney & Clark, 2016; Ranney et al., 2019). Moreover, (a) actively seeking more information about global warming (i.e., watching longer informational videos) when people could freely choose to do so (Study 4), (b) mechanistic knowledge (Studies 1, 3, and 4), and (c) acceptance (Studies 1 to 4, see Figure 5) were found to be associated with people's preexisting environmental attitude.

In summary, under rather synthetic conditions that allowed us to convince people to read about or watch climate information, we failed to comprehensively corroborate both the knowledge-deficit model (e.g., Sloman & Fernbach, 2017) and the motivated cognition assumption (e.g., B. T. Johnson & Eagly, 1989). However, under conditions that were more realistic (i.e., when people were comparatively free to decide how much time they wanted to invest in understanding the science behind global warming), we demonstrated environmental attitude's connection with the remnants of learning: knowledge and behavior (i.e., expressing acceptance and seeking information).

Implications

The presented research speaks of the incompleteness of the knowledge-deficit model for the case of accepting anthropogenic climate change (cf. van der Linden et al., 2017): although our participants substantially increased their mechanistic knowledge when exposed to climate information, their acceptance of anthropogenic climate change did not increase concurrently (Study 2; although its German participants perhaps have reacted differently than Americans). Along with others (e.g., Sinatra & Hofer, 2016), we thus conclude that mechanistic explanations alone might not always be *sufficient* for increasing people's acceptance of anthropogenic climate change and—ultimately—their engagement in climate protection.

Mechanistic explanations are apparently also not *necessary* to increase acceptance of anthropogenic climate change. Participants receiving the physical-chemical climate information afterwards expectedly trumped other participants in terms of their knowledge and

showed a significant leap in acceptance. This increase in acceptance was, however, not significantly greater than for participants who watched a video describing the consequences of climate change (but who did not learn the physical-chemical mechanism behind climate change; Study 3). Accordingly, we believe that one relevant implication of the current work is that it is important to carefully consider potential experimenter demand effects (Orne, 1962) that may drive or amplify the effects of environmental education (although effects shown upon delayed post-testing reduce the plausibility of such demand effects regarding mechanistic climate-change information; Ranney & Clark, 2016; Ranney et al., 2019). Particularly when a (mere) verbal expression of acceptance of anthropogenic climate change is the outcome measure, control groups should be exposed to climate-change-related material (e.g., the allegorical information in Study 2, and the consequences video in Study 3; see also Velautham & Ranney, 2020, who employed a mixed set of representative global warming statistics and misleading statistics that suggested global warming is not occurring). Although any participant (i.e., regardless of experimental condition) may feel that indicating elevated acceptance of anthropogenic climate change is socially-desirable, participants in no-intervention control groups may concurrently feel that they should *not* indicate elevated levels of acceptance, particularly in pre-post designs. Therefore, we believe that no-intervention control groups provide limited information as control for experimenter demand exerted through the intervention under consideration. In addition to well-designed control groups, future research may also decouple mechanistic information about how global warming works from the contentious topic of climate change—perhaps by simply teaching people about wavelengths, greenhouse gases, and heat—thus potentially both reducing demand characteristics for some participants and reactance for others.[7]

Whereas randomly allocating participants to treatment and control conditions should prevent the *researched cause* from being mixed with potential *confounders*, certain conclusions about a *cause-effect relation* might nonetheless be premature. Previous research

testing the effectiveness of climate information has failed to control for the effect of participants' preexisting environmental attitude as a well-established correlate of both environmental knowledge (e.g., Arcury, 1990) and acceptance of anthropogenic climate change (e.g., Bord et al., 2000). Thus, previous research could not definitively rule out the possibility of a spurious relationship between knowledge (rather than presented information) and acceptance (see, e.g., Shannon, 2004). For instance, people can be changed by the coherence and clarity of some mechanistic information, even should they eventually retain little of the details (Ranney et al., 2016, pp. 160-161). Given findings of increased post-instruction acceptance after 34 days (Ranney & Clark, 2016), though, it would be odd for the details to be fully inactive.

Moreover, and in line with the current findings, people may be differentially inclined to learn about the origins of global warming depending on their environmental attitude, which in turn also correlates with acceptance of anthropogenic climate change as we showed rather consistently across our four studies (see Figure 5). Despite tenacious claims of a "gap" between environmental attitude and ecological behavior (see, e.g., Gifford, 2014; Kollmuss & Agyeman, 2002), the presented research thus adds to the host of findings demonstrating the relevance of environmental attitude for people's manifest ecological behavior in a variety of domains, such as shopping (Taube & Vetter, 2019), mobility (Taube, Kibbe, Vetter, Adler, & Kaiser, 2018), and nutrition (Kaiser, Henn, & Marschke, 2020). Across domains, the mean correlation between environmental attitude and ecological behavior was moderate (r = .42; Bamberg & Möser, 2007). Further adding to this picture, Study 4 demonstrated that actively and voluntarily seeking knowledge about climate change was a related to participants' environmental attitude. We thus consider it likely that irrespective of whether and how much people's climate-change-related beliefs can be changed by mechanistic information (see e.g., Ranney & Clark, 2016; Ranney et al., 2019; Velautham & Ranney, 2020; Velautham et al.,

2019; for evidence that they are), the beliefs as such are also shaped by people's attitudes, or, in other words, by what people prefer to believe.

Limitations

A number of limitations should be taken into account when interpreting the results of our research. First, we conducted all four studies online, which may lead some to question participants' attentiveness to the informational material provided and their fidelity in responding to the knowledge questions. However, the baseline knowledge levels and subsequent increases after receiving the climate information parallel previous findings obtained in a classroom setting in which looking up the answers would have been considered cheating (see Ranney & Clark, 2016). Moreover, we employed plagiarism detection software and excluded participants who copied their answers to the knowledge questions verbatim from the Internet.

A second potential limitation concerns our measure of the acceptance of anthropogenic climate change. Rather than relying exclusively on participants' forthrightness and capacity for introspection, we suggest that future research assessing the effect of providing information on the mechanism behind global warming may benefit from employing field observations and laboratory assessments of behavior (for an overview, see Lange & Dewitte, 2019) or acceptance measures with demonstrated construct validity.

More broadly, future research on the effectiveness of environmental education in general and climate instructions more specifically needs to provide systematic explanations for why such instructions sometimes work and sometimes seem to not. A few potentially significant methodological differences from prior work ought to be mentioned: for instance, German as opposed to US participants in Studies 1-3, possible order effects among measures, and the wording of the instructions that we employed. (See Munnich & Ranney, 2019 for a discussion of the importance of a knowledge-pretest to spawn surprise; see Ranney & Clark, 2016 for a discussion of the importance of assuring participants that the information provided

is true; see D. R. Johnson, 2017 for the importance of instructing participants to focus on the quality of the mechanistic explanation.) Apart from methodological specificities, we suggest that a starting point for such future attempts would be to acknowledge the variety of interventions and potential moderators under investigation, which likely reflect a variety of assumptions about underlying psychological mechanisms.

In the current research, in line with Ranney and Clark (2016), we explained to our participants *what the current scientific consensus consists of*, hoping that "mechanistic knowledge can 'break ties' among contentious positions if initial information spawns ambivalence" (Ranney & Clark, 2016, p. 51). However, correlational research has suggested that knowledge about the operation of natural processes is merely a distal predictor, with action-oriented knowledge and connectedness to nature mediating its effect on people's ecological behavior (Roczen, Kaiser, Bogner, & Wilson, 2014). Other recent interventions have merely emphasized the extraordinary *degree of scientific consensus* on anthropogenic global warming (Bolsen & Druckman, 2018; Kahan et al., 2011), thus strengthening a potential "gateway belief" that has replicably been found to increase global warming acceptance and concern, as well as acceptance of its human causation, and, in turn has led to changes in support for public action (van der Linden, Leiserowitz, & Maibach, 2019). Yet other recent work has indicated that the following are also effective for directly increasing acceptance of anthropogenic climate change: (a) interventions contrasting graphs of Earth's temperature increases and equities' valuation increases, (b) information about sea level rise, and (c) interventions providing feedback on participants' estimates of climate statistics (Ranney & Clark, 2016; Ranney et al., 2019; Velautham & Ranney, 2020; Velautham et al., 2019). Perhaps most pertinent to the current research question, a variety of potential moderators have been put forward to test for motivated reasoning, ranging from self-rated social and economic conservatism (Ranney & Clark, 2016, etc.), nationalism (Ranney et al., 2019, etc.) and cultural worldviews (i.e., hierarchy–egalitarian vs. individualist–

communitarian; see Kahan et al., 2011) to political party identification (Bolsen & Druckman, 2018) and environmental attitude in our research. We believe it is unlikely that the effectiveness of the variety of different interventions (and the assumptions regarding potential moderators) hinges on a common psychological mechanism. Yet, these psychological mechanisms need to be explicated and tested if research in environmental education is to deliver reliable answers on how to further people's acceptance that climate change is caused by humans.

Conclusion

The presented research indicates that it is not always easy to promote acceptance of anthropogenic climate change in one-shot experimental interventions. In line with the previous successes of brief interventions explaining global warming's physical-chemical mechanism (Ranney & Clark, 2016; Ranney et al., 2019), our findings suggest that providing mechanistic information increased people's knowledge. Filling people's deficit in mechanistic knowledge was, however, neither always sufficient nor necessary to provide increased acceptance scores. Crucially, we found that both acceptance and actively seeking more information about global warming were related to people's preexisting environmental attitude. Our results also imply an encouragement for efforts to further people's acceptance that climate change is human-made: the effects of the interventions on knowledge and acceptance were both not moderated by environmental attitude. Thus, at least we found no indication of people's positions being moved further apart through the provision of information.

The data of this research can be retrieved from https://osf.io/xeu67/

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Endnotes

[1] Ranney and Clark (2016, Appendix A–also see it for a longer, 400-word explanation) suggested the following brief, mechanistic explanation for global warming: "Earth transforms sunlight's visible light energy into infrared light energy, which leaves Earth slowly because it is absorbed by greenhouse gases. When people produce greenhouse gases, energy leaves Earth even more slowly—raising Earth's temperature" (p. 74).

[2] In Studies 1-3, we aimed to recruit a heterogeneous sample by targeting mailing lists and news groups related to a broad range of interests including: car tuning, carnival, gardening, horseback riding, line dancing, motor cycles, soccer, social science research, and traveling.

[3] The pattern of all findings remains unchanged without excluding any participants, with the notable exception of the bivariate associations between mechanistic knowledge and the other constructs in Study 4, which are nonsignificant without exclusions (i.e., uncorrected for plagiarism). See https://osf.io/xeu67/ for a full report without exclusions.

[4] Grounding attitude measurement in behavior is an idea originally proposed by Donald T. Campbell (1963). According to this idea, attitude measurement should make use of the figurative "cost" of implementing a certain behavior. Behavior here refers to any manifest, unequivocally describable activity that can be observed either with scientific methods of investigation (e.g., a mark on a survey or achievement on a test) or in everyday mundane activities (e.g., reading a book or watching a video). In this view, a person's attitude becomes apparent in the behavioral costs she or he ignores (see Kaiser et al., 2010; Kaiser & Wilson, 2019).

[5] Different item sets of seven to nine items were used in the four studies. To account for differences in the various instruments, we tested the effects on participants' acceptance of anthropogenic climate change exclusively *within* studies. In line with Ranney and Clark (2016), our measures of acceptance of anthropogenic climate change also include items that

do not directly refer to climate change being human caused (e.g., "Global warming (or climate change) isn't a significant threat to life on Earth").

[6] Study 2 also included a follow-up test administrated 4 weeks after the intervention reassessing acceptance and environmental attitude. The results of this follow-up essentially mirrored what we had found on the initial posttest: Neither the original nor the allegorical mechanistic explanation was able to significantly raise participants' acceptance or attitude beyond the control group's levels (all *p*s > .29). Moreover, in both Studies 2 and 3, we offered participants information on how to reduce their energy consumption (i.e., action-related knowledge; see Roczen et al., 2014) and checked whether the mechanistic explanation would increase the rate by which participants opted in to receive this information. Again, we found no significant differences between any of the groups (all *p*s > .79). We also assessed further sociodemographic descriptors including party affiliation and education completed. The full dataset of the current research is available here: https://osf.io/xeu67/.

[7]We would like to acknowledge that this intriguing idea originates from one of our reviewers.

Tables

Table 1

Descriptive Statistics and Bivariate Correlations of Environmental Attitude, Acceptance of Anthropogenic Climate Change, and Mechanistic Global Warming Knowledge in Studies 1 to 4 and at Different Measurement Points

				Pretest			Posttest			Follow-up	
		M	*SD*	EA_1	AC_1	KN_1	EA_2	AC_2	KN_2	EA_3	AC_3
Study 1	EA_1	0.22	0.83	.76	.61	.26					
	AC_1	6.61	1.29	.49*	.86	.43					
	KN_1	1.49	1.79	.21*	.35*	.78					
Study 2	EA_1	0.12	0.87	.76				.42	.18	.82	.45
	AC_2	7.01	0.96	.31*				.73	.31	.51	.99
	KN_2	3.47	2.51	.14				.23*	.77	.30	.39
	EA_3	0.27	0.90	.62*				.38*	.23*	.76	.53
	AC_3	6.94	0.96	.36*				.75*	.30*	.41*	.78
Study 3	EA_1	0.83	1.01	.76	.42			.43	.17		
	AC_1	6.94	1.32	.32*	.83			1.00	.08		
	AC_2	7.09	1.32	.35*	.88*			.86	.08		
	KN_2	3.78	2.84	.14*	.07			.07	.88		
Study 4	EA_1	-0.28	0.86	.76	.51	.33[a]	.97	.54	.17[a]		
	AC_1	7.23	1.24	.42*	.89	.25 [a]	.44	1.00	.30[a]		
	KN_1	2.86	1.99	.29*	.24	-	.17[a]	.24[a]	.33[b]		
	EA_2	-0.36	0.91	.74*	.36*	.15	.76	.53	.17[a]		
	AC_2	7.37	1.26	.44*	.96*	.23*	.44*	.91	.26[a]		
	KN_2	4.59	2.60	.15	.28*	.33*	.15*	.25*	-		

Note. EA = Environmental Attitude, AC = Acceptance of Anthropogenic Climate Change, KN = Mechanistic Global Warming Knowledge. Indices indicate measurement points: 1 = preintervention, 2 = postintervention, 3 = follow-up. The bivariate correlations are Pearson *r*s, either uncorrected for measurement error attenuation (below the diagonal) or corrected for attenuation (above the diagonal). A generic correction for attenuation adjusts the correlations for the reliabilities of the two measures involved (Charles, 2005). Widely accepted

significance tests are available only for uncorrected correlations, so significance estimates are not given for the corrected correlations. Reliability estimates are provided in the grey shaded diagonal cells.

[a] Single correction for attenuation due to a missing reliability estimate for one of the two measures. [b] No correction for attenuation due to missing reliability estimates for both of the measures.

*$p < .05$.

Figures

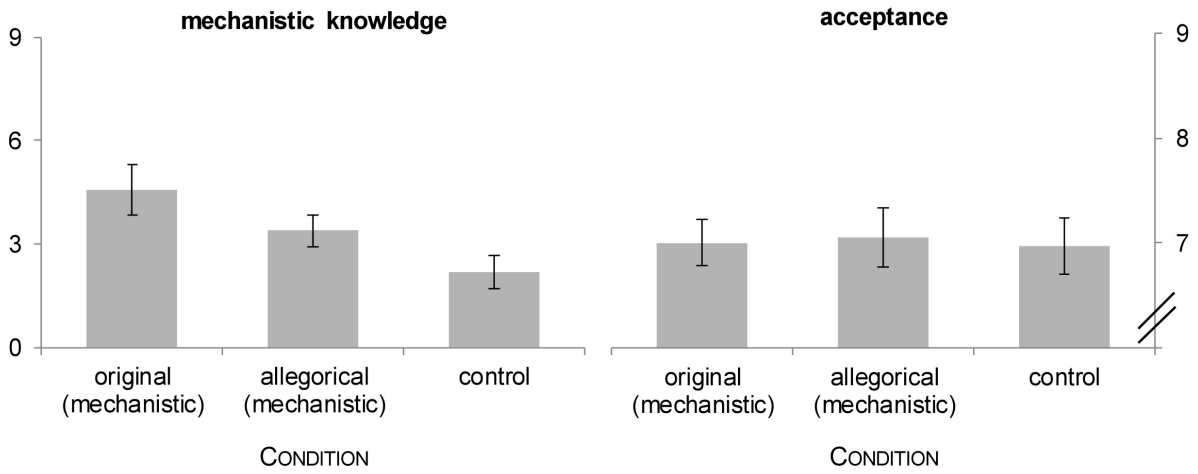

Figure 1. Mechanistic global warming knowledge (left panel) and acceptance of anthropogenic climate change (right panel) of Study 2's participants as a function of experimental condition. Means are presented with 95% confidence intervals.

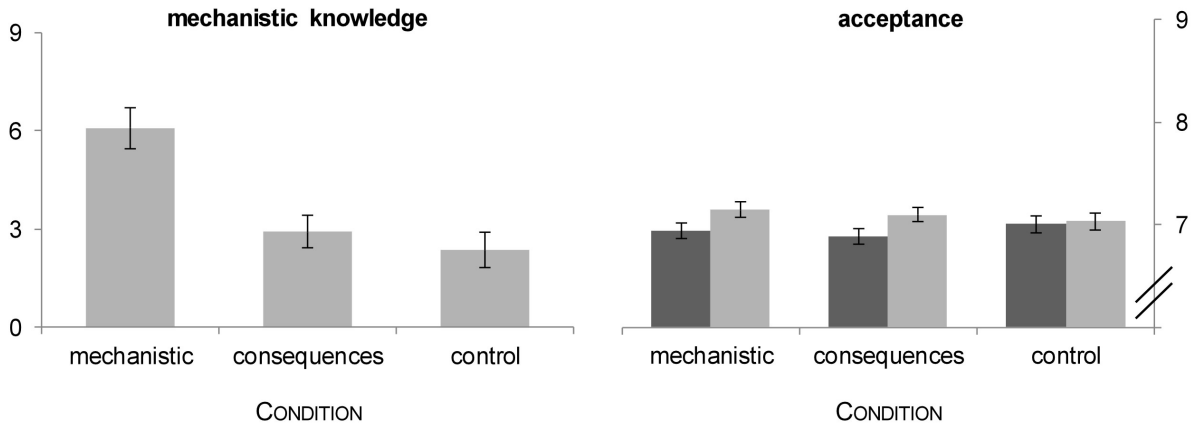

Figure 2. Mechanistic global warming knowledge (left panel) and changes in acceptance of anthropogenic climate change (right panel) of Study 3's participants as a function of condition. Means are presented with 95% confidence intervals. Dark grey bars represent pretest values, and light grey bars represent posttest values. Confidence intervals for acceptance were calculated with Loftus and Masson's (1994) procedure for repeated-measures designs.

Figure 3. Video selection in Study 4 (no-video default condition).

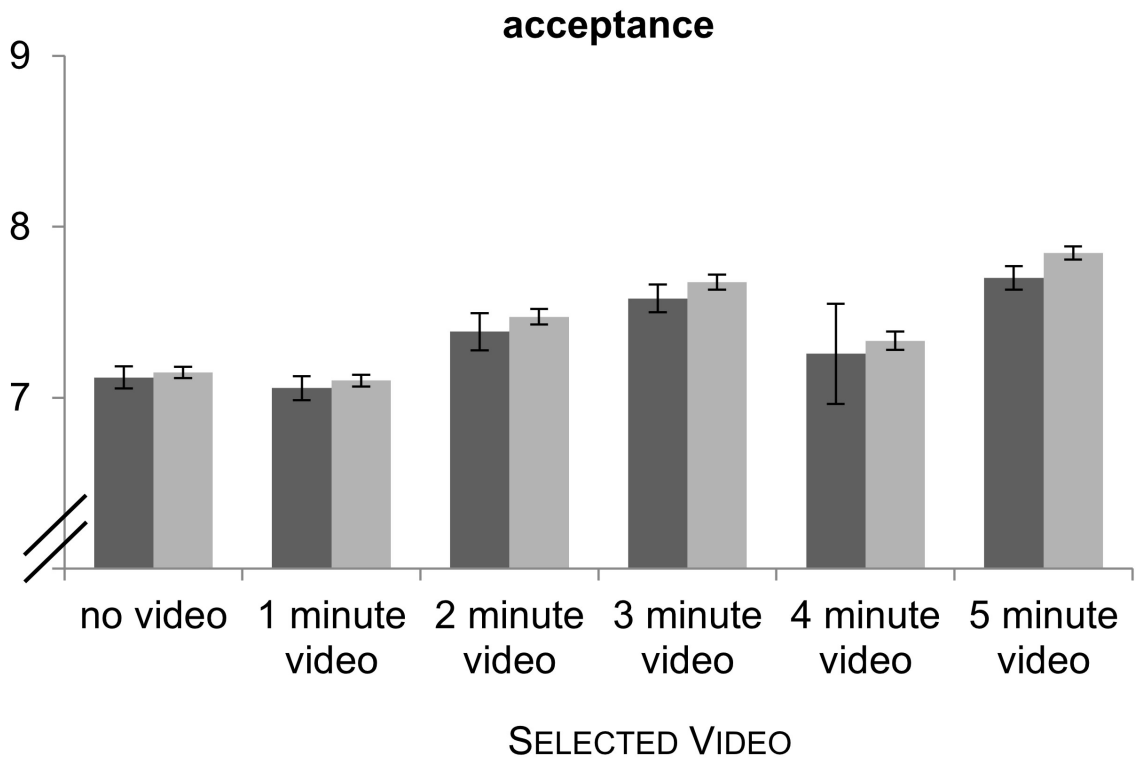

Figure 4. Changes in acceptance of anthropogenic climate change of Study 4's participants as a function of the length of the video explaining global warming's mechanism selected by participants. Means are presented with 95% confidence intervals. Dark grey bars represent pretest values (n = 137), and light grey bars represent posttest values (n = 269; greater by design). The comparatively large confidence interval for the acceptance pretest of participants choosing the four-minute video is due to the very small number of participants choosing to watch this video (n = 8, with n = 26 choosing the two-minute video being the second smallest value). Confidence intervals were calculated with Loftus and Masson's (1994) procedure for repeated-measures designs.

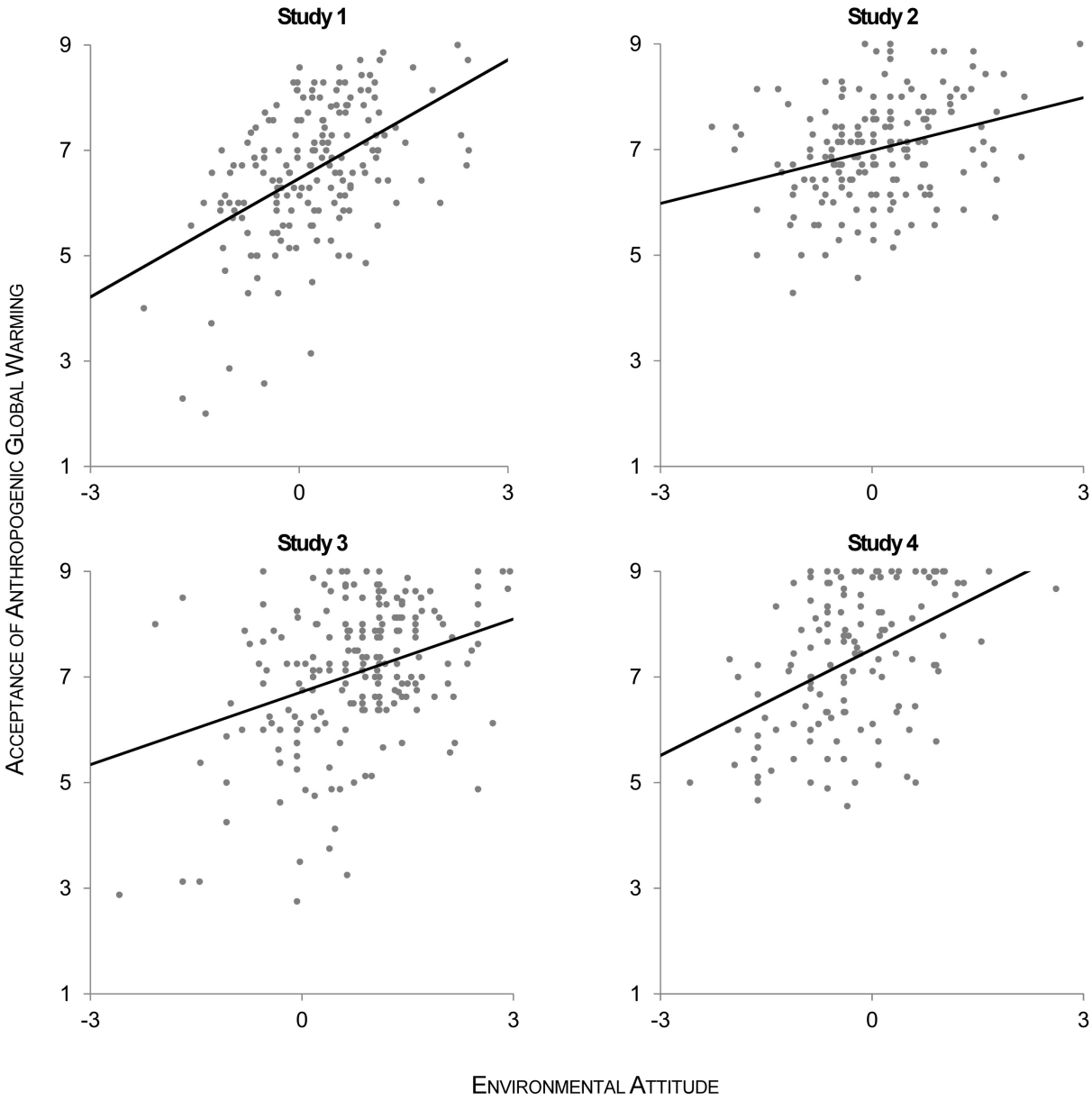

Figure 5. Acceptance of anthropogenic climate change in Studies 1 to 4 as a function of participants' baseline environmental attitude (in logits). For Studies 2 to 4, postintervention acceptance levels are displayed.