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RESEARCH ARTICLE

Framing of Geoengineering Affects Support for Climate Change Mitigation

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ABSTRACT
The growing recognition that climate change mitigation alone will be inadequate has led scientists and policymakers to discuss climate geoengineering. An experiment with a US sample found, contrary to previous research, that reading about geoengineering did not reduce conservatives' skepticism about the existence of anthropogenic climate change. Moreover, depending on how it is framed, geoengineering can reduce support for mitigation among both conservatives and non-conservatives. When geoengineering is framed as a major solution, people worry less about climate change, leading to reduced mitigation support. When framed as disastrous, people perceived geoengineering as riskier, also leading to a decrease in mitigation support. A more moderate framing of geoengineering as a partial solution is less susceptible to moral hazard effects. Overall, results suggest that geoengineering will not lessen political polarization over anthropogenic climate change, and could undercut support for mitigation efforts. Instead, framing geoengineering as a small piece to solving a big puzzle seems to be the best strategy to weaken this potential moral hazard.

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Climate change; geoengineering; moral hazard; mitigation support; risk compensation

1. Introduction

In the face of mounting evidence of the dire consequences of climate change (IPCC, 2013) and the insufficient implementation of mitigation policies, researchers and policymakers are giving serious thought to geoengineering: intentional manipulation of the Earth's climate (Horton, Keith, & Honegger, 2016; National Research Council, 2015b, 2015a). One frequently discussed form of geoengineering is solar radiation management (SRM), in which aerosols are injected into the stratosphere to increase planetary albedo and counteract warming (Shepherd et al., 2009). Yet exactly how reading about SRM will affect other climate-related beliefs and behaviors—especially in the politically polarized domain of US climate policy—is still unknown.

2. Is geoengineering a foot in the door or a moral hazard for conservatives on climate?

There are two principle objections to SRM. The first is that SRM may cause unintended environmental harms or even be used for warfare (National Research Council, 2015b). The second is a "moral hazard" objection, that consideration of SRM will dampen support for policies to reduce

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greenhouse gas emissions (Lin, 2013; National Research Council, 2015b).[1] Other researchers have referred to this phenomenon as a risk compensation effect, by which knowledge about a remedy to the impacts of a risk lulls people into a reduced fear of that risk (Carrico, Truelove, Vandenbergh, & Dana, 2015).

Supporting this second fear, some technology-based solutions to climate change (e.g. carbon dioxide removal) seem to undermine support for mitigation (Campbell-Arvai, Hart, Raimi, & Wolske, 2017). Similarly, messages conveying optimism about the rate of emissions reductions can dampen motivation for mitigation (Hornsey & Fielding, 2016). Research on SRM in particular has found that laypeople fear that SRM will create a moral hazard among others, although that study did not test whether those participants engaged in risk compensation themselves (Corner & Pidgeon, 2014).

To date, only a handful of studies have tested whether information regarding SRM can affect support for mitigation policies. Counter to the moral hazard argument, one study (Merk, Pönitzsch, & Rehdanz, 2016) found that reading about geoengineering actually increased Germans' willingness to invest in mitigation. Yet these findings may not apply to the United States: Concern about climate change and support for mitigation policies is unusually strong and relatively unpolarized in Germany (Dunlap, McCright, & Yarosh, 2016; Stokes, Wike, & Carle, 2015).

Work in the US and UK found that when presented with an extremely optimistic account of geoengineering, hierarchical individualists (who tend to be conservative) expressed stronger belief in the risks of climate change and greater trust in a scientific article about climate change (Kahan, Jenkins-Smith, Tarantola, Silva, & Braman, 2015). However, this study did not test whether geoengineering affected support for governmental mitigation policies. The distinction is important: Geoengineering would still pose a moral hazard if people's belief in climate change increased but support for mitigation decreased. Research showing a gap between climate belief and policy support (Raimi, Stern, & Maki, 2017; Saad, 2017) suggests that this possibility is a serious concern. After all, climate change beliefs do not directly affect response to climate change; climate change policies do. Thus, any action that increases belief but simultaneously undermines support for action may arguably do more harm than good.

Conservatives in the United States may be drawn to geoengineering because it seems to offer a means of avoiding regulatory responses to climate change—this is explicitly how it has been framed in previous research (Kahan et al., 2015). In fact, they often reject climate science *because* of proposed regulatory, government-centered solutions (Campbell & Kay, 2014). Thus, whereas conservative belief in climate science might increase in response to a technological silver bullet that avoids regulation, this belief may not translate into acceptance of mitigation-related regulation.

Supporters of the (conservative) UK Tory party did not shift their support for a carbon tax after reading about geoengineering (Fairbrother, 2016). However, participants in that study were given only a snippet of text about geoengineering that did not address its efficacy, costs or risks. These factors are especially important given the newness of geoengineering among the lay public. How such tradeoffs are described may have a large influence on how people perceive these issues, as they have little else to guide their assessments.

Based in part on the research above, some have suggested that geoengineering may be a useful foot in the door to engage a highly polarized public about climate change science and solutions more generally (Carr, Yung, & Preston, 2014; Kahan et al., 2015). Similarly, discussing climate change in ways that are more amenable to values such as support for free markets and technological innovation may lead conservatives to views more in line with those of the scientific consensus, and may make them more willing to consider mitigation policies (Campbell & Kay, 2014; Feygina, Jost, & Goldsmith, 2010; Howell, Capstick, & Whitmarsh, 2016; Maki, Vandenbergh, Cohen, & Gilligan, 2016). Yet the extent (or even direction) of these effects may depend on how geoengineering is framed.

3. The role of framing in geoengineering discourse

In political and policy discourse, geoengineering generally and SRM in particular have been framed in three principal ways. Technological enthusiasts and some policymakers frame SRM as a comprehensive and relatively inexpensive solution to the problem of climate change (Ikle & Wood, 2007; Klein, 2012), which we call a "major solution" frame. For example, former Speaker of the US House of Representatives Newt Gingrich has stated that geoengineering "holds forth the promise of addressing global warming concerns for just a few billion dollars a year" (Feldmann, 2011). This is also how geoengineering was presented to participants in previous climate communication experiments (Kahan et al., 2015). At the other extreme, some view SRM as so dangerous that it should not even be studied (Hamilton, 2013), which we consider a "disaster" frame. Finally, some see SRM as a temporary means to buy time until measures drastically reducing greenhouse gas emissions can be implemented (Moreno-Cruz & Keith, 2013; Wigley, 2006). We call this a "minor solution" frame.

Framing may be particularly effective in current discussions of geoengineering, as the public is still largely unfamiliar with these technologies (Borick & Rabe, 2012; Scheer & Renn, 2014). Given this lack of knowledge, we suspect that early communication about these technologies could have a large impact on how people assess their benefits and risks. Thus, although framings of climate change often have weak (and sometimes non-robust) effects on overall climate change belief due to people's preexisting entrenchment on the issue (McCright, Charters, Dentzman, & Dietz, 2016), framings of new ideas like geoengineering may have a particularly strong influence on public discourse.

4. Current research

This experimental research tested five hypotheses. First, based on previous research, we thought that reading about geoengineering could increase belief in anthropogenic climate change among political conservatives (H1). However, we also hypothesized that discussions of geoengineering could act as a moral hazard and thus undermine support for mitigation regulations (H2). We thought that the way geoengineering was framed would affect the existence and strength of any moral hazard effects (H3). Specifically, framing SRM as a major solution to climate change could create a moral hazard by lulling people into the belief that climate change has been solved. Thus, even if geoengineering bolstered conservative belief in climate change, a major solution framing of the issue could still reduce support for mitigation. Framing geoengineering as a minor solution, on the other hand, inherently conveys the idea that other approaches are required. Therefore, this less optimistic framing should be less likely to undermine support for these other approaches. Lastly, when SRM is presented as a disaster, a framing that offers a very unappealing alternative to mitigation policies, we might even expect increased support for regulation, as people are reminded of the overall risks of climate change (and non-mitigation approaches). However, the disaster framing could also backfire. Overly dire messages about climate change can lead to disengagement (Feinberg & Willer, 2011), so it may be that disastrous pronouncements about SRM work the same way.

We expected that the effect of geoengineering framing on moral hazard could work through at least two potential processes. First, we thought that reading about geoengineering could reduce people's level of worry about climate change, which would in turn reduce support for regulatory climate policies (H4a). Therefore, even if people (especially conservatives) had increased acceptance of the science after reading about geoengineering, they could simultaneously believe that the technology they read about took away the threat climate change poses. On the other hand, we thought that discussions of geoengineering could increase the risks that people perceived SRM to pose, and that this fear about non-regulatory approaches to climate change could increase support for mitigation policies (H4b).

Finally, we thought that any moral hazard effects would be particularly pronounced among conservatives given their relative eagerness to avoid regulations (H5). We thought that this could show up both in the direct effects of reading about geoengineering on policy support and as part of a mediated effect. Past moral hazard research has found political ideology to moderate the link between (reduced) perceptions of climate change threat and support for emission-reduction policy. Specifically, this reduced threat leads to less policy support especially among political conservatives (Campbell-Arvai et al., 2017). If such an effect were found, it would suggest that when sufficiently worried about climate change, conservatives are just as supportive of mitigation regulation as liberals; but that absent this worry (such as might be the case after reading about technological solutions like SRM), conservatives reject mitigation policies.

Given the findings of Kahan that reading about SRM increased climate risk perceptions among conservatives (Kahan et al., 2015), we also tested whether political ideology moderated the extent to which geoengineering affected climate change worry. However, other research has found no such moderating effects on risk perceptions (Campbell-Arvai et al., 2017; Carrico et al., 2015), so we thought any such effects might be weak.

5. Methods

5.1. Participants

Participants were 780 adults recruited via Amazon's Mechanical Turk (MTurk). Thirty-one participants were removed from the dataset for failing an attention check; all analyses that follow were with the remaining sample ($N = 749$; 46.5% Male; $M_{age} = 36.39$). This sample was less ethnically and racially diverse than US Census averages (Humes, Jones, & Ramirez, 2011): 80.5% self-identified as White/Caucasian, 10.4% as Black/African-American, 8.3% as Hispanic or Latino, 7.6% as Asian, 2.3% as American Indian or Alaska Native, and 2.5% as Other.[2] Median education was a bachelor's degree (higher than US Census averages) and median income was $35,000–49,999 (less than US Census averages) (Proctor, Semega, & Kollar, 2016; Ryan & Bauman, 2016). Political ideology (*Very conservative* = −2 to *Very liberal* = 2) was normally distributed with a slightly left-of-center average ($M = 0.31$, $SD = 1.06$).

5.2. Procedure and measures

Participants were randomly assigned to read one of four brief newspaper articles about climate change (see Appendix). In three conditions, the article also described SRM. In the major solution condition, SRM was described as a "great" solution to climate change, one in which "we wouldn't have to do much more to stop the worst effects of climate change." In the minor solution condition, participants read that SRM is at most a temporary solution, which would still require us to "do more to stop the worst effects of climate change." In the disaster condition, SRM was described as having great risks: "playing with the climate at such a grand scale could be disastrous." A fourth (control) article did not mention geoengineering. These descriptions were kept short to convey a basic understanding of geoengineering rather than a full explanation of the various mechanisms and technologies that might be involved in SRM. They were modeled after previous research on SRM that has used similarly brief explanations and graphics (Fairbrother, 2016; Kahan et al., 2015). The condensed nature of these descriptions comes at a cost of external validity, as real newspaper articles would likely explain the various potential technologies and mechanisms of SRM in greater detail. However, this approach allowed us to test the psychological mechanisms involved more cleanly; manipulation checks confirmed that the experimental conditions affected beliefs about climate change and geoengineering as expected (see Appendix). Following the experimental manipulation, participants answered three climate change belief questions adapted from previous surveys (Maibach, Roser-Renouf, & Leiserowitz, 2009). The first asked "Do you think climate change is happening?" with response options of *Yes, No, or I don't know*. The second asked, "Assuming climate change is happening, do you think it is:" with options of *caused mostly by human activities, caused mostly by* *natural changes in the environment, none of the above because global warming isn't happening,* or *other (with a fill-in answer textbox)*. Participants who indicated an even split between human and non-anthropogenic causes were scored as halfway between these two causes. The product of these two items was used as a composite belief score. Possible scores ranged from 0 (indicating that climate change is either not happening or non-anthropogenic) to 1 (belief in anthropogenic climate change), with mid-range scores for those who were unsure about the existence of climate change or indicated an even split between human and natural causes. A third question asked participants "How much risk do you believe climate change poses to human health, safety, or prosperity?" (*No risk* = 0 to *Extreme risk* = 10).

Participants' personal feelings of worry about climate change were assessed with the item, "How personally worried are you about climate change?" (*Not at all worried* = 1 to *Extremely worried* = 5). Participants were also asked, "How risky do you think it would be to use the approach described in the news story to deal with climate change" (*Not at all* = 1 to *A great deal* = 4). Participants could also indicate the question was not applicable if no solution had been mentioned in the article (as was the case for those in the control condition).

We then asked participations about their support or opposition to nine climate change mitigation policies, with responses ranging from (*Strongly oppose* = 1 to *Strongly support* = 5). The policies included signing of an international treaty to reduce emissions from the US and other countries, requiring car manufacturers to increase the fuel efficiency of their vehicles, increasing subsidies for renewable energy such as wind and solar power, a tax on fuel based on the amount of greenhouse gases emitted by that fuel, requiring appliance manufacturers to increase the efficiency of energy using appliances, building more nuclear power plants, encouraging individuals to use less energy in their home and vehicles, reducing emissions of large electric generating facilities and factories, and setting a limit to greenhouse gas emissions with a system such as "cap and trade". These items were combined into a composite measure of mitigation policy support ($\alpha = .86$).

Finally, participants reported their demographics and political ideology.

6. Results

We created dummy codes for each experimental condition (1 if in that condition, 0 if not), with the control condition as the reference group. Ideology was not mean-centered, but was kept such that the intercept of 0 indicated endorsement of a moderate position, negative scores reflected conservative ideology, and positive scores indicated liberal ideology. Descriptive statistics and correlations between all post-treatment variables are shown in Table 1. See Figure 1 for overall effects of condition on all outcome variables.

> H1: Does reading about geoengineering increase belief in anthropogenic climate change among political conservatives?

Two hierarchical linear regressions (HLR) first tested the effects of condition, ideology, and their interaction on climate change beliefs and perceived risk (Table 2; Figure 2). Interactions were probed at the midpoint of the ideology scale (moderates) and at 1SD below and above the midpoint (conservatives and liberals, respectively). Significant interactions emerged for both outcomes.

Table 1. Descriptive statistics and correlations between post-treatment variables.

	Mean (SD)	1	2	3	4
1. Belief in anthropogenic climate change	0.74 (0.42)	–			
2. Perceived risk of climate change	6.87 (2.66)	0.64	–		
3. Climate change worry	3.20 (1.13)	0.54	0.73	–	
4. Perceived risk of SRM	2.94 (0.92)	−0.05	−0.05	−0.00	–
5. Mitigation policy support	3.81 (0.74)	0.56	0.67	0.59	−0.12

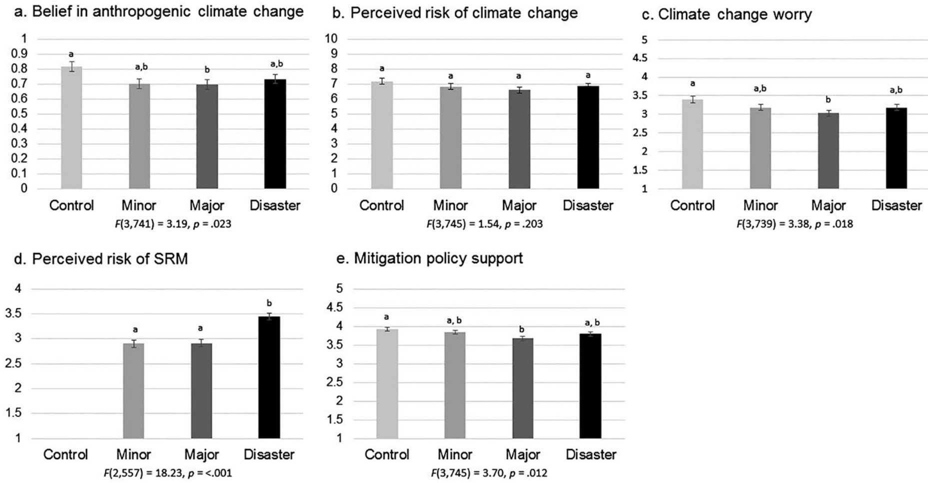

Figure 1. Effects of condition on dependent measures. Means and standard errors of post-treatment variables, by condition. Results are from one-way ANOVAs. Subscripts that differ indicate significant differences in post-hoc comparisons using Sidak corrections. Climate change belief scores range from 0 (climate change not happening or not anthropogenic) to 1 (full endorsement of human-caused climate change). Perceived risk scores range from 0 (no risk) to 10 (extreme risk). Climate change worry ranges from 1 (not at all worried) to 5 (extremely worried). Perceived risk of SRM ranges from 1 (not at all) to 4 (a great deal). Mitigation policy support ranges from 1 (strongly oppose) to 5 (strongly support).

Specifically, conservatives and moderates who read any of the three geoengineering descriptions had weaker belief in anthropogenic climate change than those in the control condition (Figure 2a). This effect was more pronounced among conservatives ($b_{\text{Minor}} = -0.18$, $t(736) = -2.58$, $p = .010$; $b_{\text{Major}} = -0.27$, $t(736) = -4.20$, $p < .001$; $b_{\text{Disaster}} = -0.23$, $t(736) = -3.42$, $p < .001$) than among moderates ($b_{\text{Minor}} = -0.12$, $t(736) = -2.89$, $p = .004$; $b_{\text{Major}} = -0.14$, $t(736) = -3.32$, $p < .001$; $b_{\text{Disaster}} = -0.10$, $t(736) = -2.52$, $p = .012$). Reading about geoengineering did not significantly affect the climate change beliefs of liberals ($b_{\text{Minor}} = -0.06$, $t(736) = -1.32$, $p = .186$; $b_{\text{Major}} = 0.00$, $t(736) = 0.06$, $p = .954$; $b_{\text{Disaster}} = 0.02$, $t(736) = 0.43$, $p = .666$).

Table 2. Effect of condition and ideology on belief in anthropogenic climate change, climate change risks, and mitigation policy support.

	Anthropogenic Climate Change				Climate Risk				Mitigation Policy Support			
Predictor	*b*	*SE*	*p*	sr^2	*b*	*SE*	*p*	sr^2	*b*	*SE*	*p*	sr^2
Minor	−0.11	0.04	.010	.01	−0.34	0.28	.219	.00	−0.08	0.08	.275	.00
Major	−0.10	0.04	.007	.01	−0.59	0.28	.033	.01	−0.25	0.08	.001	.01
Disaster	−0.08	0.04	.056	.00	−0.34	0.27	.218	.00	−0.13	0.08	.085	.00
Step 1	$\Delta F(3,740) = 3.16$, $p = .024$, $\Delta R^2 = .01$				$\Delta F(3,744) = 1.53$, $p = .204$, $\Delta R^2 = .01$				$\Delta F(3,744) = 3.69$, $p = .012$, $\Delta R^2 = .02$			
Ideology	0.18	0.13	<.001	.20	1.19	0.08	<.001	.22	0.31	0.02	<.001	.20
Step 2	$\Delta F(1,739) = 185.17$, $p < .001$, $\Delta R^2 = .20$				$\Delta F(1,743) = 216.46$, $p < .001$, $\Delta R^2 = .22$				$\Delta F(1,743) = 186.297$, $p < .001$, $\Delta R^2 = .20$			
Minor x Ideo.	0.05	0.04	.187	.00	0.19	0.24	.428	.00	−0.02	0.07	.781	.00
Major x Ideo.	0.13	0.04	.001	.01	0.64	0.23	.005	.01	0.11	0.06	.081	.00
Disaster x Ideo.	0.11	0.04	.003	.01	0.57	0.23	.012	.01	0.14	0.06	.035	.00
Step 3	$\Delta F(3,736) = 4.99$, $p = .002$, $\Delta R^2 = .02$				$\Delta F(3,740) = 3.58$, $p = .014$, $\Delta R^2 = .01$				$\Delta F(3,740) = 2.88$, $p = .035$, $\Delta R^2 = .01$			
Full Model	$F(7,736) = 30.74$, $p < .001$, $R^2 = .23$				$F(7,740) = 33.64$, $p < .001$, $R^2 = .24$				$F(7,740) = 30.04$, $p < .001$, $R^2 = .22$			

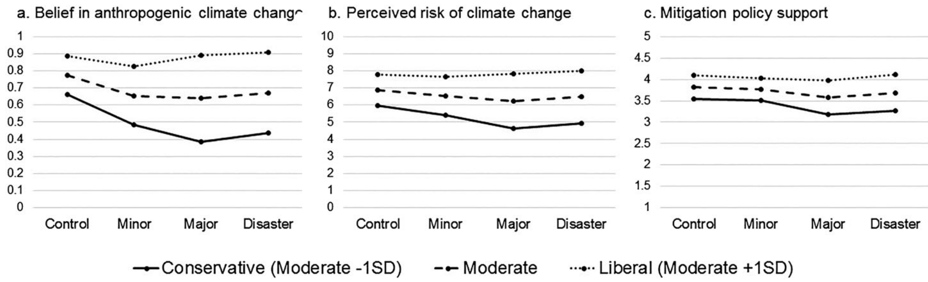

Figure 2. Effects of geoengineering on climate beliefs. Belief in anthropogenic climate change (2a), perceived risk (2b), and policy support (2c) by condition and political ideology. Climate change belief scores range from 0 (climate change not happening or not anthropogenic) to 1 (full endorsement of human-caused climate change). Perceived risk scores range from 0 (no risk) to 10 (extreme risk). Mitigation policy support ranges from 1 (strongly oppose) to 5 (strongly support). Political ideology is shown at 0 (moderate) and at one standard deviation above and below the moderate point.

For perceptions of the risk of climate change, conservatives and moderates in the major solution condition also saw climate change as less of a risk ($b_{Con} = -1.34$, $t(740) = -3.30$, $p < .001$; $b_{Mod} = -0.64$, $t(740) = -2.50$, $p = .013$), as did conservatives (but not moderates) in the disaster condition ($b_{Con} = -1.02$, $t(740) = -2.52$, $p = .012$; $b_{Mod} = -0.39$, $t(740) = -1.56$, $p = .120$; Figure 2b). Neither conservatives nor moderates had significant differences in climate risk perceptions after reading that geoengineering was a minor solution as compared to control ($b_{Con} = -0.53$, $t(740) = -1.26$, $p = .208$; $b_{Mod} = -0.32$, $t(740) = -1.26$, $p = .207$). Liberals' perception of climate risk was not affected by any of the experimental manipulations ($b_{Minor} = -0.12$, $t(740) = -0.39$, $p = .700$; $b_{Major} = 0.06$, $t(740) = 0.06$, $p = .828$; $b_{Disaster} = 0.24$, $t(740) = 0.80$, $p = .422$).

Thus, H1 was not supported: Unlike in previous studies (Kahan et al., 2015), geoengineering did not increase belief in or perceptions of risk about climate change among the political right. On the contrary, reading about geoengineering *decreased* these beliefs among political conservatives and moderates. The extent of this decrease varied by the way geoengineering was framed, but in no case did reading about geoengineering increase belief in anthropogenic climate change or its attendant risk.

H2 & H3: Does reading about geoengineering act as a moral hazard, undermining policy support?

A one-way analysis of variance (ANOVA) found a significant effect of condition on policy support (Figure 1e). Pairwise comparisons showed that participants in the major solution condition were less supportive of mitigation policies that those in the control condition. Those in the minor solution and disaster conditions reported lower policy support than the control, although this was not a significant difference. Thus, H2 was partially supported: At least one type of framing of SRM undermined support for mitigation regulations, and the others trended in the same direction. Furthermore, H3 was supported: The extent that SRM information created a moral hazard depended on how geoengineering was framed, with the major solution condition causing the greatest moral hazard.

H4a: Do moral hazard effects work by reducing worry about climate change?

We next tested the mechanism by which reading about geoengineering undermines policy support. We had hypothesized that reading about SRM would lull people into a (false) sense of security about climate change, thus lessening their perceived need to act to reduce emissions. Therefore, we tested whether people's feelings of worry about climate change mediated the effect of condition on policy support (Figure 3a). All mediation analyses were conducted using the PROCESS macro for SPSS (Hayes, 2013) with 10,000 bootstrapping iterations.

When worry was included in the model as a mediator, none of the experimental conditions directly affected support for mitigation (PROCESS MODEL 4; Figure 3a; Table 3). However, there was a significant indirect effect, whereby those who read that SRM would be a major solution

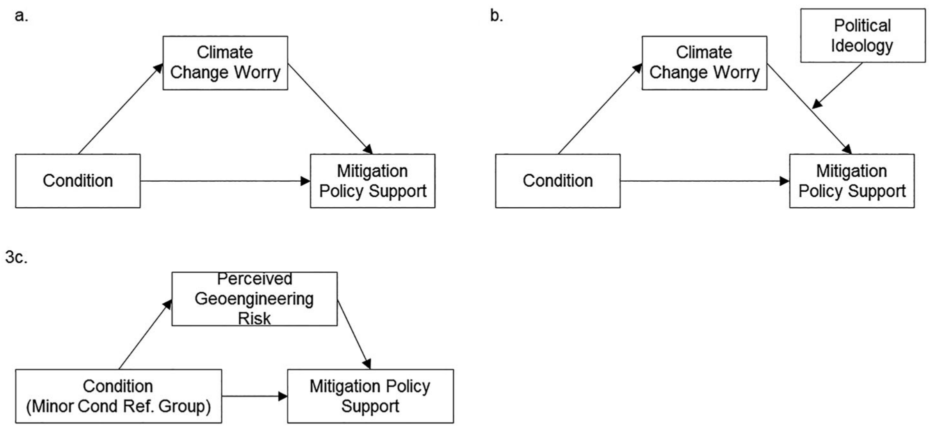

Figure 3. Conceptual models of mediation analyses. Figure 3a (PROCESS Model 4) tested direct and indirect effects of condition on mitigation support via climate change worry. Figure 3b (PROCESS Model 14) was a moderated-mediation analysis allowing political ideology to moderate the effect of worry on policy support. Figure 3c (PROCESS Model 4) tested direct and indirect effects of condition on mitigation support via perceived risk of geoengineering, with the minor solution condition as the reference group.

reported a decreased amount of worry about climate change, and in turn were less inclined to support mitigation. As with the direct tests using ANOVA, the indirect effects of the minor solution and disaster conditions on policy support through worry were not significant, but trended in the same direction as the major solution condition. Thus H4a was supported: Where moral hazard effects occurred, they did so via reduced worry about climate change.

H4b: Do increased fears about SRM increase support for mitigation policy?

A second set of mediation analyses tested whether the way SRM is described affects perceived risks of geoengineering, and in turn, whether this affects mitigation support. The control group was excluded from these analyses, as they had not read about SRM; instead, the minor solution condition was used as the reference group (PROCESS MODEL 4; Figure 3c). Being in the disaster condition (as compared to the minor solution condition) led participants to rate geoengineering as riskier (Table 4). No such effect emerged in the major solution condition. Yet surprisingly, the riskier participants rated geoengineering, the less they supported mitigation policies. Thus, we found an indirect effect whereby being told SRM would be disastrous undermined support for mitigation by way of increased perception of geoengineering's risks. This ran counter to the hypothesized direction, and so we did not find support for H4b.

H5: Are moral hazard effects stronger among political conservatives?

We had hypothesized that any moral hazard effects would be more pronounced among political conservatives than liberals. Therefore, we tested whether political ideology moderated the direct effect of condition on mitigation policy support, and whether it moderated the mediated effect of condition on policy support via worry. As with the tests of H1, interactions were probed for moderates (0), conservatives (1SD below scale midpoint), and liberals (1SD above midpoint).

First, a HLR tested whether condition, ideology, and their interaction affected support for mitigation policies (Table 2; Figure 2c). Here, the interaction was only significant for those in the disaster condition: Conservatives (but not moderates or liberals) who read that geoengineering would be disastrous were less supportive of mitigation policies than those in the control condition ($b_{Con} = -0.29$, $t(740) = -2.50$, $p = .013$; $b_{Mod} = -0.14$, $t(740) = -1.93$, $p = .054$; $b_{Lib} = 0.01$, $t(740) = 0.15$, $p = .883$). The interaction between ideology and major solution condition was marginally significant. Probing this interaction showed that conservatives and moderates in the major solution condition were less supportive of policy than control participants; the effect for liberals was in the same direction but not

Table 3. Mediation (Model 4) and moderated–mediation (Model 14) analyses testing effects of conditions on mitigation policy support, mediated by worry about climate change and (in Model 14), moderated by political ideology.

	Direct Predictors of Climate Change Worry (PROCESS Models 4 and 14)					
Predictor	*Coeff.*	*SE*	*t*	*p*	95% CI	R^2
Intercept	0.20	0.08	2.43	.015	(0.04, 0.37)	.02
Minor Condition (a_{11})	−0.22	0.12	−1.86	.064	(−0.45, 0.01)	
Major Condition (a_{12})	−0.37	0.12	−3.16	.002	(−0.60, −0.14)	
Disaster Condition (a_{13})	−0.22	0.12	−1.87	.061	(−0.45, 0.01)	

	Direct Predictors of Mitigation Policy Support											
	PROCESS Model 4						PROCESS Model 14					
Predictor/mediator	*Coeff.*	*SE*	*t*	*p*	95% CI	R^2	*Coeff.*	*SE*	*t*	*p*	95% CI	R^2
Intercept	3.84	0.04	85.61	<.001	(3.76, 3.93)	.35	3.85	0.04	88.99	<.001	(3.77, 3.94)	.43
Minor Condition (c_{11}')	0.01	0.06	0.09	.932	(−0.12, 0.13)		−0.01	0.06	−0.10	.924	(−0.12, 0.11)	
Major Condition (c_{12}')	−0.10	0.06	−1.64	.102	(−0.23, 0.02)		−0.09	0.06	−1.59	.111	(−0.21, 0.02)	
Disaster Condition (c_{13}')	−0.04	0.06	−0.68	.498	(−0.17, 0.08)		−0.02	0.06	−0.41	.681	(−0.14, 0.09)	
Climate Worry (b_1)	0.38	0.02	19.36	<.001	(0.34, 0.42)		0.32	0.02	15.54	<.001	(0.28, 0.36)	
Ideo. (b_2)							0.15	0.02	7.00	<.001	(0.11, 0.20)	
Climate Worry * Ideo. (b_3)							−0.11	0.02	−7.1	<.001	(−0.15, −0.08)	

	Indirect Predictors of Mitigation Policy Support						
	PROCESS Model 4			PROCESS Model 14			
Predictor/mediator	*Coeff.*	*Boot SE*	Boot 95% CI	*Ideo.*	*Coeff.*	*Boot SE*	Boot 95% CI
Minor Condition (a_{11})	−0.09	0.04	(−0.17, 0.00)	Con.	−0.10	0.05	(−0.20, 0.00)
				Mod.	−0.07	0.04	(−0.15, 0.00)
				Lib.	−0.04*	0.02	(−0.09, −0.00)
				IMM	0.02*	0.01	(0.00, 0.06)
Major Condition (a_{12})	−0.14*	0.05	(−0.23, −0.05)	Con.	−0.16*	0.05	(−0.27, −0.06)
				Mod.	−0.12*	0.04	(−0.20, −0.05)
				Lib.	−0.07*	0.02	(−0.13, −0.03)
				IMM	0.04*	0.02	(0.02, 0.08)
Disaster Condition (a_{13})	−0.08	0.05	(−0.17, 0.00)	Con.	−0.10	0.05	(−0.20 0.00)
				Mod.	−0.07	0.04	(−0.15, 0.00)
				Lib.	−0.04*	0.02	(−0.09, −0.00)[a]
				IMM	0.02*	0.01	(0.00, 0.06)

Note: *$p < .05$
Ideo. = political ideology, Con = conservative, Mod = moderate, Lib = liberal, IMM = Index of moderated mediation
[a]Values for liberals in the minor solution and disaster conditions look identical due to rounding

Table 4. Mediation analyses (Model 4) testing effects of disaster and major solution frames (compared to minor condition) on mitigation, mediated by perceived geoengineering risk.

	Direct Predictors of Geoengineering Risk					
Predictor	*Coeff.*	*SE*	*t*	*p*	95% CI	R^2
Intercept	−0.24	0.07	−3.59	<.001	(−0.36, −0.11)	.14
Major Condition (a_{11})	−0.00	0.09	−0.02	.985	(−0.18, 0.18)	
Disaster Condition (a_{12})	0.70	0.09	7.79	<.001	(0.52, 0.88)	
	Direct Predictors of Mitigation Policy Support					
Predictor/mediator	*Coeff.*	*SE*	*t*	*p*	95% CI	R^2
Intercept	3.81	0.06	65.06	<.001	(3.69, 3.92)	.02
Major Condition (c_{11}')	−0.11	0.08	−1.34	.182	(−0.27, 0.05)	
Disaster Condition (c_{12}')	0.04	0.08	0.44	.658	(−0.13, 0.20)	
Geoengineering Risk (b_1)	−0.11	0.04	−2.65	.008	(−0.18, −0.03)	
	Indirect Predictors of Mitigation Policy Support					
Predictor/mediator	*Coeff.*	*Boot SE*	Boot 95% CI			
Major Condition (a_{11})	0.00	0.01	(−0.02, 0.02)			
Disaster Condition (a_{12})	−0.07*	0.03	(−0.13, −0.02)			

Note: *$p < .05$

significant ($b_{Con} = -0.37$, $t(740) = -3.20$, $p = .001$; $b_{Mod} = -0.24$, $t(740) = -3.39$, $p < .001$; $b_{Lib} = -0.12$, $t(740) = -1.42$, $p = .155$). The minor solution condition did not differ from the control at any level of political ideology ($b_{Con} = -0.04$, $t(740) = -0.30$, $p = .768$; $b_{Mod} = -0.06$, $t(740) = -0.77$, $p = .442$; $b_{Lib} = -0.08$, $t(740) = -0.90$, $p = .370$).

Our first test of H5 was thus partially supported, in that geoengineering undermined policy support more strongly for conservatives than liberals, though this interaction was only significant for those in the disaster condition (and marginal for the major solution condition). We next tested whether the mediated effects found earlier were moderated by political ideology.

We had mixed a priori hypotheses about how political ideology might moderate the link between condition and climate change worry. On the one hand, we thought that if geoengineering increased political conservative's acceptance of climate science, that it could also increase their feelings of worry to match those of liberals, although other risk compensation research has not found this effect (Campbell-Arvai et al., 2017; Carrico et al., 2015). However, we also suspected that political ideology might moderate the link from worry to mitigation support. Campbell-Arvai et al. (2017) had found that when sufficiently worried about climate change, conservatives showed similar support for mitigation policies as liberals did, but that reading about some climate technologies reduced that worry. Therefore, we started by using a model (PROCESS Model 59) that allows political ideology to moderate all links in the mediation model. However, most interactions were not significant, and so we used a more parsimonious model (PROCESS Model 14; Figure 3b; Table 3) that allows political ideology to moderate the link between worry and mitigation support, but does not include the (non-significant) moderation of the link between condition and worry. The indices of moderated mediation were significant for all three conditions, indicating that the indirect effects of SRM condition on policy support differed by political ideology (Hayes, 2015).

Specifically, replicating Campbell-Arvai et al. (2017), conservatives were especially unlikely to support mitigation if they had low levels of climate change worry (see Figure 4). Although all participants were less likely to support mitigation after reading that SRM was a major solution to climate change due to their diminished worry, these effects were particularly pronounced among conservatives. Unexpectedly, liberals in the minor solution and disaster conditions were also less likely to support mitigation due to lessened climate worry. The pattern was the same for conservatives and moderates in those conditions, but nonsignificant. These effects were weaker than those in the major solution condition, but suggest that any framing of geoengineering may (at least somewhat)

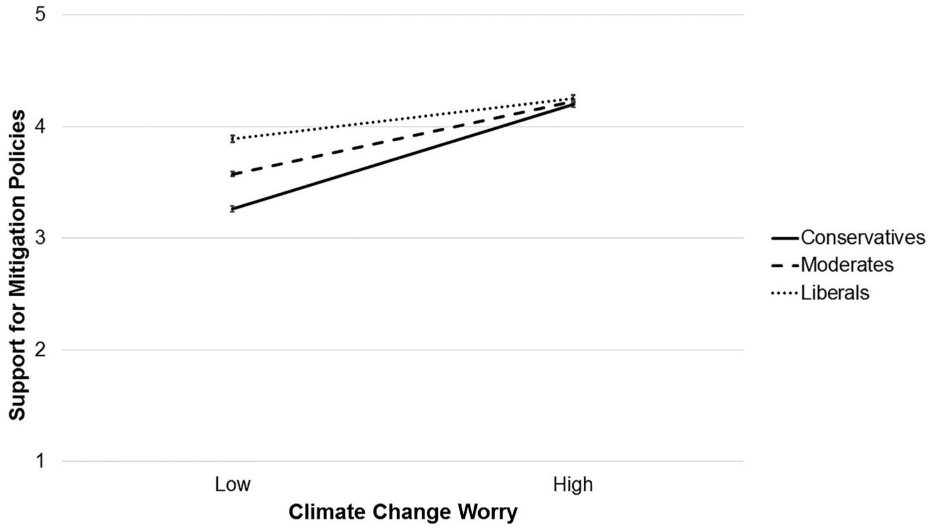

Figure 4. Effects of climate worry and political ideology on mitigation policy support. Interaction of climate worry and ideology on support for mitigation policy (Model 14). Support for mitigation policies scores range from 1 (strongly oppose) to 5 (strongly support). Political ideology is shown at the midpoint of the scale (moderate) and at one standard deviation below (conservative) and above (liberal) the midpoint. Error bars represent standard error.

undermine support for mitigation via reduced worry. Thus, we found evidence for H5, in that the strength of moral hazard effects was strongest among conservatives in the major solution condition, and strongest among liberals in the other conditions.

Again, starting with PROCESS Model 59, we tested whether political ideology moderated the mediation of condition on mitigation support by way of perceived SRM risk. However, neither the relationship between condition and perceived SRM risk nor that between SRM risk and mitigation support were moderated by political ideology. Thus, while H5 was supported by way of climate worry, political ideology did not play a significant role in undermining mitigation support by way of perceived geoengineering risks.

7. Discussion

This study sheds light on how the public might react to increased inclusion of solar radiation management in climate change discussions. Unlike previous research, the current study found no evidence that reading about geoengineering increased conservative's beliefs in anthropogenic climate change or the risks climate change causes; on the contrary, we found that reading about geoengineering decreased these beliefs. Furthermore, we found evidence that geoengineering can create a moral hazard, by way of undermining people's worry about climate and (paradoxically) by increasing their fears about SRM.

7.1. Geoengineering and perceptions of climate change

Contrary to our hypothesis (H1) and previous research (Fairbrother, 2016; Kahan et al., 2015), we found that political conservatives who read either of the two extreme depictions of SRM (the major and disaster framings) had lessened belief in anthropogenic climate change and its attendant risks, compared to those in the control.

There are several possible reasons that the current results differ from those reported elsewhere. The first has to do with our samples. The previous studies used nationally representative samples, whereas our study drew on a non-representative panel (Amazon's Mechanical Turk: MTurk).

Although nationally representative samples are preferred, and MTurk tends to oversample liberals (Paolacci & Chandler, 2014), liberals and conservatives recruited via MTurk respond similarly to liberal and conservatives drawn from nationally representative samples (Clifford, Jewell, & Waggoner, 2015). Thus, it seems unlikely that the participants in our study were vastly different than those drawn from more representative samples. Yet given limitations in MTurk and other convenience samples (Chandler, Mueller, & Paolacci, 2014), differences in sample populations could be a possible reason for this discrepancy.

Second, our identity measures were slightly different. We measured political ideology, whereas Kahan et al. scored participants on hierarchy and individualism, in line with studies on cultural cognition (Kahan et al., 2015; Kahan, Jenkins-Smith, & Braman, 2011). These measures sometimes differ from ideology-based predictions (Kahan et al., 2011). Yet, conceptually, cultural cognition is very similar to ideological motivated reasoning (van der Linden, 2016), and reactions of hierarchical individualists to climate change mirror those of conservatives (Kahan et al., 2012). Fairbrother (2016) used (UK) political affiliation rather than ideology. The different interpretations of the science among the US public following geoengineering information may be due in part to greater political entrenchment over climate change in the US as compared to the UK and other European countries (McCright, Dunlap, & Marquart-Pyatt, 2016).

Rejection of anthropogenic climate change may be too much a tenet of faith among some self-identified American conservatives for them to discard it, even when presented with a technological solution to climate change that implicitly avoids prescriptive government regulation. If this interpretation is correct, only in cases where regulatory approaches are *explicitly* deemed unnecessary, as they were in Kahan et al. (2015), do US conservatives feel free to endorse the science.

7.2. Geoengineering as a moral hazard

Geoengineering does appear to be a moral hazard (supporting H2), and the framing of SRM is an important factor (supporting H3). The strength of framing effects may be due in part to the public's relatively low level of awareness and understanding about geoengineering (Scheer & Renn, 2014). Without pre-existing perceptions of geoengineering to guide them, people are likely to be swayed by their first exposure to the topic. The extent to which framing matters may dissipate with increased public discourse around geoengineering, but at this stage framing is still vital and suggests that two common ways of discussing geoengineering are particularly counterproductive to mitigation efforts.

The first framing, in which SRM is described as a comprehensive and low-cost technological solution to climate change, acts as a moral hazard by decreasing people's worry about climate change (supporting H4a). This pattern provides evidence for the risk compensation hypothesis that reading about new climate solutions might lower concerns about climate risks and thus limit subsequent action (Carrico et al., 2015). It also extends research finding the same moral hazard when people learn about technological strategies to remove carbon dioxide from the atmosphere (Campbell-Arvai et al., 2017). In both cases, these effects were strongest among conservatives (supporting H5). This result suggests that any boost that geoengineering may provide to conservative belief in climate science (Fairbrother, 2016; Kahan et al., 2015) is not translated into support for the policies that are a necessary accompaniment to technological climate solutions.

The second framing, in which critics decry SRM's potential for disastrous side effects (Hamilton, 2013), may also be detrimental to the push for mitigation. Reading about the disastrous consequences of geoengineering succeeded in heightening participants' perceptions of the risks of this technology; however, these risk perceptions had the effect of decreasing support for mitigation policies (counter to H4b). Exactly why these effects occurred is open to further exploration. One possibility is that participants experienced a sense of fatalism after reading about the disastrous potential of geoengineering, believing that if such a risky solution is being discussed, then we must be out of options. This interpretation is similar to the remarks by libertarian US presidential candidate Gary Johnson, who argued that the fact that the Sun will collide with Earth someday negates the need to act on climate change (Schulman, 2016). Another possibility is that the apocalyptic message of the disaster framing contradicts people's belief that the world is stable and just (Feinberg & Willer, 2011), thus leading them to reject both the science of climate change and any policies to regulate greenhouse gas emissions.

The Goldilocks approach—wherein geoengineering is described as a minor solution—may thus be the best way to frame geoengineering for all individuals if the goal is to educate the public about this technology without losing support for mitigation. Rather than arguing that geoengineering is a magic silver bullet or that it will lead to disaster, science communicators, journalists and policymakers should instead focus on its potential incremental value as one element of a multi-pronged climate change response. Yet it is worth noting that even this frame undermined mitigation support to some degree; future research should seek to uncover additional framings of SRM that promote, rather than weaken, mitigation support.

One caveat to this literature in the very brief descriptions of SRM given to participants in this and the previous experiments (Fairbrother, 2016; Kahan et al., 2015). In the real world, news consumers are likely to encounter much more detailed explanations of SRM, including more details on potential technologies and techniques, more explication of tradeoffs, and more coverage of uncertainties. Future research should explore whether providing more tradeoffs affects perceptions of SRM and/or the downstream consequences of about geoengineering.

8. Conclusion

As the opportunity to fully prevent climate change fades, it is natural for scientists and policymakers to treat geoengineering as a possible (or even necessary) consideration. Yet as this discourse begins in the public realm, we must remember the importance of how these approaches are framed. Given the current lack of public awareness about geoengineering, climate communicators have a rare chance to get out ahead of the discussion and frame the debate in constructive ways. The current research suggests that extreme depictions of geoengineering, whether apocalyptic or miraculous, often undermine support for policy approaches to reduce emissions. Instead, framing geoengineering as a small piece to solving a big puzzle seems to be the best strategy to weaken this potential moral hazard.

Data availability

All datasets and codebooks have been uploaded to the Open Science Framework (OSF) website at https://osf.io/tchz4/.

Note

1. We note that theorists have delineated various types of moral hazards (Hale, 2012). This study specifically refers to hazards resulting in diminished support for mitigation policies.
2. Categories were not mutually exclusive: Participants could check all that applied.

Disclosure statement

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Appendices

Experimental Conditions

Participants were randomly assigned to read one of the four brief newspaper articles below.

Control Condition

Scientists: Serious Consequences of Climate Change
by Samuel Harvey
Oct 15, 2015

WASHINGTON, D.C. – Recent reports from the Intergovernmental Panel on Climate Change suggest that previous estimates of the impacts of global warming were far too optimistic. These new reports suggest that the planet is warming and the seas are rising at a rate much faster than previously feared.

Climate scientists say:
- Climate change impacts could be serious

Dr. Peter Shaw, a leading geophysicist, argues, "We need to start taking more action on climate change." According to scientists, there are a wide variety of ways to manage the effects of climate change.

Minor Solution Condition

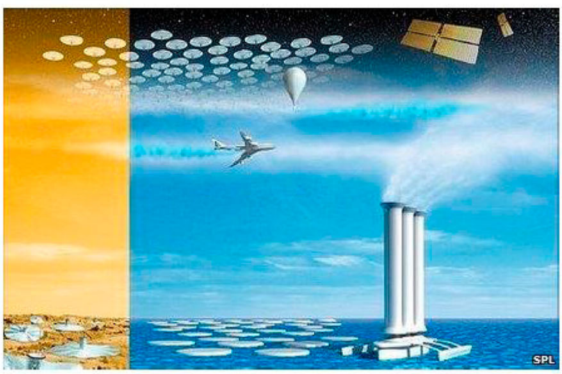
Scientists: Geoengineering Can Only Manage Some Risks
by Samuel Harvey
Oct 15, 2015

WASHINGTON, D.C. – Recent reports from the Intergovernmental Panel on Climate Change suggest that previous estimates of the impacts of global warming were far too optimistic. These new reports suggest that the planet is warming and the seas are rising at a rate much faster than previously feared.

Climate scientists say:
- Climate change impacts could be serious
- Geoengineering can only manage a small amount of the impacts of climate change

Dr. Peter Shaw, a leading geophysicist, argues, "Technological solutions can only manage some of the impacts of climate change. Geoengineering would only be a temporary solution; we'd still have to do more to stop the worst effects of climate change."

According to scientists, the most likely form of geoengineering is solar radiation management (SRM). SRM counteracts the warming effects of climate change by injecting particles of sulfate or water into the atmosphere to reflect the sun's rays back out into space.



Major Solution Condition

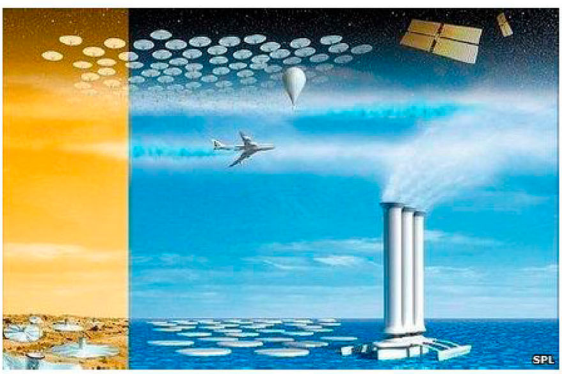
Scientists: Geoengineering Can Manage Most Risks
by Samuel Harvey
Oct 15, 2015

WASHINGTON, D.C. – Recent reports from the Intergovernmental Panel on Climate Change suggest that previous estimates of the impacts of global warming were far too optimistic. These new reports suggest that the planet is warming and the seas are rising at a rate much faster than previously feared.

Climate scientists say:
- Climate change impacts could be serious
- Geoengineering can manage most of the impacts of climate change

Dr. Peter Shaw, a leading geophysicist, argues, "Technological solutions can manage most of the impacts of climate change. Geoengineering could be a great solution; we wouldn't haven't to do much more to stop the worst effects of climate change"

According to scientists, the most likely form of geoengineering is solar radiation management (SRM). SRM counteracts the warming effects of climate change by injecting particles of sulfate or water into the atmosphere to reflect the sun's rays back out into space.



Disaster Condition

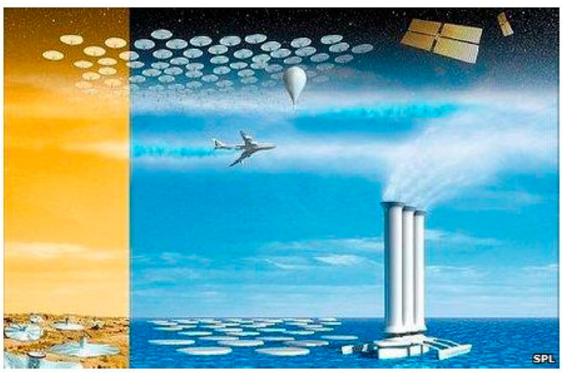
Scientists: Geoengineering is Risky
by Samuel Harvey
Oct 15, 2015

WASHINGTON, D.C. – Recent reports from the Intergovernmental Panel on Climate Change suggest that previous estimates of the impacts of global warming were far too optimistic. These new reports suggest that the planet is warming and the seas are rising at a rate much faster than previously feared.

Climate scientists say:
- Climate change impacts could be serious
- Geoengineering could have disastrous consequences

Dr. Peter Shaw, a leading geophysicist, argues, "Technological solutions to climate change are unproven. Geoengineering could have some benefits, but the risks are too high; playing with the climate at such a grand scale could be disastrous."

According to scientists, the most likely form of geoengineering is solar radiation management (SRM). SRM counteracts the warming effects of climate change by injecting particles of sulfate or water into the atmosphere to reflect the sun's rays back out into space.



Manipulation Checs

Manipulation checks confirmed that the experimental conditions affected beliefs about climate change and geoengineering as expected: Participants in the major solution condition, compared to the other conditions, were most likely to believe that we are significantly closer to solving climate change, and participants in the disaster condition were least likely to believe SRM to be effective and least likely to support SRM.

Items. A series of manipulation checks measured the success of the newspaper article. Participants first reported whether the article had said that the effects of climate change would be more harmful, more beneficial, or the same as previous assessments. A second question asked, "How close do you think we are to solving the problem of climate change?" (1 = *Very far away from solving it*; 5 = *We have already solved it*). Participants could respond that the question was not applicable ("n/a"), either because climate change was not happening or because it does not require action.

Two other questions asked participants "How effective do you think the actions described in the news article will be at helping us adapt to climate change" (*Not at all* = 1; *Extremely* = 5) and "How risky do you think it would be to use the approach described in the news story to deal with climate change" (*Not at all* = 1; *A great deal* = 4). Participants could indicate "n/a" if no solution had been mentioned in the article (as was the case for those in the control condition). This perceived geoengineering risk question was later used as a mediator for some analyses. Finally, participants in the three geoengineering conditions indicated how much they supported the actions described in the news article (*Not at all* = 1; *A great deal* = 4).

Results. A series of analyses of variance (ANOVAs) tested the effects of the experimental conditions on how close we are to solving climate change and the riskiness and effectiveness of using geoengineering. Those who selected "n/a" as their response to these questions (either because they did not believe climate change existed or did not think any solution had been described) were excluded from these analyses.

An ANOVA on the first manipulation check found that perceived progress on climate change varied by condition, $F(3,689) = 9.67$, $p < .001$. Post-hoc comparisons with Sidak corrections showed that those in major solution condition ($M = 2.27$, $SD = 0.96$) thought we were significantly closer to solving climate change than those in the minor solution ($M = 1.99$, $SD = 0.86$; $p < .05$), disaster ($M = 1.80$, $SD = 0.84$; $p < .001$), or control conditions ($M = 1.89$, $SD = 0.79$; $p < .001$); the last three conditions did not significantly vary from one another.

Other ANOVAs assessed the perceived effectiveness and risk of geoengineering. Because the control condition did not describe geoengineering, these analyses only included the three geoengineering conditions. Both perceived risk and effectiveness differed by condition (Risk: $F(2,519) = 41.34$, $p < .001$; Effectiveness: $F(2,535) = 10.66$, $p < .001$) . Specifically, participants in the disaster condition (Risk: $M = 3.40$, $SD = 0.74$; Effectiveness: $M = 2.59$, $SD = 1.17$), thought that geoengineering was significantly more risky and less effective than did those in the minor solution (Risk: $M = 2.70$, $SD = 0.88$, $p < .001$; Effectiveness: $M = 2.88$, $SD = 1.12$, $p < .05$) or major solution condition (Risk: $M = 2.70$, $SD = 0.92$, $p < .001$; Effectiveness: $M = 3.15$, $SD = 1.12$, $p < .001$). People in the minor and major solution conditions did not vary in their perceptions of the riskiness or effectiveness of geoengineering.

We also used an ANOVA to test the effect of condition on participants' support for the actions described in the passage. Participants in the control condition—who had not read about any specific actions—were excluded from this analysis. An ANOVA found a significant effect of condition, $F(2,542) = 8.25$, $p < .001$; post-hoc tests with Sidak corrections revealed that this was driven by participants in the disaster condition ($M = 2.34$, $SD = 1.03$) having less support for geoengineering than those in the major ($M = 2.71$, $SD = 1.05$) or minor solution ($M = 2.72$, $SD = 0.96$) conditions, $ps < .001$. No differences emerged between the minor and major solution conditions on support for geoengineering.