Supplementary information B of the paper: Public opinion about solar radiation management: A cross-cultural study in 20 countries around the world

Additional information on the questionnaire, provided information on SRM, and measures

Content of Supplementary information B:

Table B1. Overview of questionnaire languages per country

Cluster	Country	Questionnaire language
Global South	Argentina	Argentine Spanish
	Brazil	Brazilian Portuguese
	China	Mandarin Chinese
	Iran	Persian
	Nigeria	English
'Non-WEIRD' Global North	Kazakhstan	Russian
	Mexico	Mexican Spanish
	Russia	Russian
	Taiwan	Mandarin Chinese
	Turkey	Turkish
'WEIRD' Global North	Australia	English
	Ireland	English
	Italy	Italian
	Netherlands	Dutch
	Norway	Norwegian
	Portugal	Portuguese
	Spain	Spanish
	Switzerland	German
	UK	English
	USA	English

Supplementary note B1: Additional information on the content of the questionnaire

The questionnaire started with information on the background of the study, an informed consent, and general instructions. Then, we measured demographic variables, assessed participants' values, belief in global warming, and current perceived knowledge about and support of SRM. As research indicates that public awareness of SRM is low (Mercer et al., 2011; Merk et al., 2015; Pidgeon et al., 2012), which was confirmed in our study (see SI-A), we then provided information on SRM, specifically on stratospheric aerosol injection (Crutzen, 2006). The information was followed by two open questions on the arguments in favour and against SRM as perceived by the participants. Thereafter, we measured emotional responses, perceptions, acceptability, and attitudinal ambivalence related to SRM. The survey closed with questions on perceptions and preferences about the decision-making related to SRM. Supplementary note B2 describes the information we provided on SRM and Supplementary note B3 the measures used in this study.

Supplementary note B2: Information on SRM provided to participants

Solar Radiation Management to limit global warming?

According to the latest report by the United Nations' Intergovernmental Panel on Climate Change it is necessary to limit global warming to [1.5ºC/2.7°F] to prevent some of the worst consequences of global warming. One key action to achieve this goal is to reduce greenhouse gas emissions, especially carbon dioxide (CO_2). For example, by using less fossil fuels, such as oil and coal. An additional option to limit global warming is to use Solar Radiation Management.

What is Solar Radiation Management?

Solar Radiation Management technologies aim to send small amounts of sunlight and its heat back into space before it reaches the ground. Because less sunlight and heat would reach the ground, the Earth would be cooled. One way to do this would be to place a thin layer of sulphur particles in the air, around 20 kilometres above the Earth's surface (see figure[1] below). The sulphur particles can be put in the air by airplanes or large balloons. The process is similar to what happens after volcanic eruptions, where sulphur particles are also released in the air. Once in the air, the sulphur particles act as mirrors and send part of the sunlight and its heat back into space.

To ensure a continuous cooling effect, sunlight and heat would have to be continuously sent back into space. That means that a certain amount of sulphur particles would have to be continuously injected in the air over many years to come.

Solar Radiation Management is still in the early stages of research and development but is increasingly discussed as a supplementary measure to limit global warming to [1.5ºC/2.7°F] along with other measures, including reduction of CO_2 emissions.

Arguments in favour or against Solar Radiation Management

There are arguments in favour or against the use of Solar Radiation Management through injection of sulphur particles.

Arguments in favour:

- In contrast to other options to reduce global warming, Solar Radiation Management could slow or stop the rise in global temperatures within a few years to below [1.5ºC/2.7°F].
- Without using Solar Radiation Management, we might not manage to limit global warming to [1.5ºC/2.7°F]. The consequences of warmer global temperatures would be severe.
- Solar Radiation Management could help reduce some of the worst consequences of global warming, including:
  - Extreme weather events, such as extreme temperatures, rains, and droughts, which would have negative effects on food security, human health, and nature;
  - Sea level rise endangering the habitat of living organisms, including humans.
- The technical costs of Solar Radiation Management are expected to be lower than for other options to reduce global warming, including the reduction of CO_2 emissions.

Arguments against:

- Solar Radiation Management would not address the main cause of global warming, CO_2 emissions. Therefore, other negative effects of CO_2 emissions, such as ocean acidification, would also not be addressed.
- If Solar Radiation Management was suddenly stopped, global temperatures might increase rapidly with even more severe consequences than those from gradual global warming.

[1] Due to copy rights the figure that was displayed in the questionnaire as part of the information on SRM cannot be displayed here.

- The effects of Solar Radiation Management would differ significantly across regions. Some regions would benefit from more moderate temperatures. Other regions would suffer because Solar Radiation Management would change rainfall patterns. This would cause regional floods and droughts, threatening food security and nature in those regions.
- Solar Radiation Management could reduce or stop our efforts to reduce CO_2 emissions, which would make it even harder to truly solve the problem of global warming.

How to implement and use Solar Radiation Management?

The possible positive and negative effects of Solar Radiation Management would cross borders and affect countries unequally. Therefore, most experts agree that Solar Radiation Management should not be implemented by one or a few countries on their own. Instead, experts advocate a joint implementation by all or a vast majority of countries together, based on an international agreement. Some experts think that such a joint implementation may be possible through existing international institutions (e.g. the United Nations Framework Convention on Climate Change) or through a new international institution. Yet, other experts think that successful international cooperation that guarantees the responsible implementation and use of Solar Radiation Management is unlikely. Indeed, some experts believe that because the negative effects of Solar Radiation Management could affect some countries more than others, even a joint implementation by a vast majority of countries together could cause major conflict between countries and world regions.

Supplementary note B3: Information on the measures used in this study

Belief in global warming

We measured belief in global warming with four items adapted from van Valkengoed et al. (2021), namely (1) "Climate change is real", (2) "Human activities are the main causes of climate change", (3) "The negative consequences of climate change will be very serious", and (4) "The area I live in will be negatively influenced by climate change". The items were measured on a scale ranging from -3=*Completely disagree* to +3=*Completely agree*. In case participants completely disagreed with the first item (response option -3), the remaining items were skipped and this response (-3) was used as the participants' score in belief in global warming. For the remaining participants, the items were averaged with higher scores reflecting stronger belief in global warming.

While for the overall samples and most subsamples the internal consistencies were satisfactory (Cronbach's $\alpha > .7$; see Table B2), for a few subsamples, and especially for those from the Global South, the internal consistencies were not satisfactory (Cronbach's $\alpha < .7$; see Table B2). For these cases, we inspected whether the internal consistencies were low because a specific item did not fit the scale, which was not the case. Moreover, our findings on belief in global warming seem not affected by the partly non-satisfactory internal consistencies of the measure as the results, both from ANCOVAs and regression analyses, did not systematically differ between the subsamples with non-satisfactory internal consistencies and those with satisfactory internal consistencies.

Perceptions about SRM

Table B3 presents the items we used to measure the six perceptions about SRM and the internal consistencies for multi-item measures are presented in Table B2. All items were introduced by the sentence "I think the implementation and use of Solar Radiation Management would…", followed by a bipolar response scale that contrasted a negative perception about a consequence or characteristic of SRM with the corresponding positive perception about the consequence or characteristic. This allowed us to capture the full spectrum of a potential consequence or characteristic, e.g. from "SRM is very harmful for humans" to "SRM is very beneficial for humans", rather than only (dis)agreement

with one side of the spectrum, such as (dis)agreement with "SRM is very harmful for humans". Notably, such item-specific response options have been found to result in better quality responses than (dis)agreement response options (Saris et al., 2010).

To keep the length of the survey acceptable, it was not feasible to measure each perception with a multi-item measure. Yet, research indicates that unidimensional concepts can be measured validly with a single item, if the content validity of the item is maximised (Nagy, 2002; Rossiter, 2011). Accordingly, for unidimensional concepts, single-item measures were applied for which the primary design criterion was maximal content validity (i.e. semantic correspondence of the concept and the measure).

We had originally aimed at measuring separately participants' perceptions about (a) the impacts of SRM on humans (IPCC, 2018, 2022, 2023), (b) the impacts of SRM on nature and the environment (IPCC, 2018, 2022, 2023), and (c) whether or not SRM would disturb or tamper with nature (Pidgeon et al., 2013; Visschers et al., 2017). Yet, the items measuring the three perceptions were strongly associated with each other (see Table B4) and were thus averaged to reflect perceptions about the impacts of SRM on humans and nature (for similar findings see Jobin & Siegrist, 2020; Visschers et al., 2017).

Acceptability of SRM

We measured acceptability of SRM with four items adapted from previous research on acceptability of innovations (Contzen, Handreke, et al., 2021; Contzen, Perlaviciute, et al., 2021). The four items were introduced by the sentence "I think the implementation and use of Solar Radiation Management is…", followed by four bipolar response scales. They read (1) -3=…*very negative* to +3=…*very positive*, (2) -3=…*very unnecessary* to +3=…*very necessary*, (3) -3=…*very bad* to +3=…*very good*, and (4) -3=…*very unacceptable* to +3=…*very acceptable.* The items were averaged.

Table B2. Internal consistencies[1] for multi-item measures for the overall samples and per sub-sample

		Cronbach's α						Spearman-Brown coefficient			
		Belief in global warming		SRM is positive for humans and nature		SRM is acceptable		SRM increases mitigation efforts		SRM affects countries equally	
		S	GP	S	GP	S	GP	S	GP	S	GP
	Full sample	.79	.83	.88	.92	.91	.94	.82	.84	.86	.88
Global South	Argentina	.62	--	.89	--	.93	--	.78	--	.87	--
	Brazil	.83	--	.90	--	.93	--	.84	--	.91	--
	China	.69	--	.87	--	.91	--	.82	--	.88	--
	Iran	.67	.69	.87	.88	.90	.92	.78	.77	.84	.89
	Nigeria	.66	--	.82	--	.83	--	.65	--	.72	--
'Non-WEIRD' Global North	Kazakhstan	.73	.76	.89	.88	.88	.90	.77	.70	.84	.84
	Mexico	.82	--	.90	--	.94	--	.79	--	.85	--
	Russia	.75	--	.87	--	.91	--	.79	--	.84	--
	Taiwan	.79	.78	.85	.94	.91	.94	.79	.84	.88	.91
	Turkey	.79	--	.90	--	.93	--	.83	--	.87	--
'WEIRD' Global North	Australia	.69	--	.90	--	.93	--	.82	--	.88	--
	Ireland	.78	.85	.87	.91	.91	.94	.79	.82	.84	.84
	Italy	.79	.90	.94	.94	.96	.96	.89	.90	.84	.89
	Netherlands	.72	.83	.82	.90	.88	.93	.84	.87	.82	.88
	Norway	.72	.81	.84	.87	.91	.91	.84	.82	.85	.87
	Portugal	--	.76	--	.93	--	.95	--	.88	--	.89
	Spain	.66	.81	.91	.93	.94	.95	.82	.88	.86	.92
	Switzerland	.71	.88	.84	.93	.93	.97	.87	.80	.84	.94
	UK	.77	.82	.88	.91	.89	.95	.80	.83	.81	.87
	USA	.86	.86	.89	.93	.91	.93	.84	.72	.85	.82

Note. S=Students. GP=General public. [1] For scales with more than two items, Cronbach's α is presented and for two-item measures the Spearman-Brown coefficient (Eisinga et al., 2013).

Table B3. Items used to measure perceptions about SRM

Concepts and items -3=negative pole	+3=positive pole
Perception that SRM would limit global warming	
[SRM would] be very ineffective to limit global warming.	[SRM would] be very effective to limit global warming.
Perception that SRM would address the causes of global warming	
[SRM would] totally not address the causes of global warming.	[SRM would] totally address the causes of global warming.
Perception that SRM would increase mitigation efforts	
[SRM would] very much reduce politicians' efforts to reduce CO_2 emissions.	[SRM would] very much increase politicians' efforts to reduce CO_2 emissions.
[SRM would] very much reduce citizens' efforts to reduce CO_2 emissions.	[SRM would] very much increase citizens' efforts to reduce CO_2 emissions.
Perception that SRM would have positive impacts on humans and nature	
[SRM would] be very harmful for humans.[1]	[SRM would] be very beneficial for humans.[1]
[SRM would] be very harmful for me personally.[1]	[SRM would] be very beneficial for me personally.[1]
[SRM would] be very bad for nature.[2]	[SRM would] be very good for nature.[2]
[SRM would] have a very negative impact on the environment.[2]	SRM would] have a very positive impact on the environment.[2]
[SRM would] be a very unnatural thing to do.[3]	[SRM would] be a very natural thing to do.[3]
[SRM would] very much disturb the order of nature.[3]	[SRM would] very much restore the order of nature.[3]
Perception that SRM would be inexpensive.	
[SRM would] be very expensive.	[SRM would] be very inexpensive.
Perception that SRM would affect countries equally	
[SRM would] have very unequal benefits across countries.	[SRM would] have very equal benefits across countries.
[SRM would] pose very unequal risks across countries.	[SRM would] pose very equal risks across countries.

Note. S=Students. GP=General public. [1] Items had been intended to measure people's perception about the impacts of SRM on humans. [2] Items had been intended to measure people's perception about the impacts of SRM on nature and the environment. [3] Items had been intended to measure people's perception about whether or not SRM would disturb or tamper with nature.

Table B4. Associations between the items measuring different perceptions about SRM among students (above the diagonal) and among the general public (below the diagonal)

	Limits warming	Addresses causes	Increases efforts 1	Increases efforts 2	Positive humans 1	Positive humans 2	Positive nature 1	Positive nature 2	In line nature 1	In line nature 2	Inexpen-sive	Equal effects 1	Equal effects 2
Limits warming		0.29***	0.20***	0.21***	0.42***	0.49***	0.41***	0.42***	0.31***	0.35***	0.16***	0.23***	0.22***
Addresses causes	0.37***		0.44***	0.43***	0.40***	0.44***	0.43***	0.42***	0.42***	0.42***	0.08***	0.35***	0.37***
Increases efforts 1	0.24***	0.45***		0.70***	0.33***	0.37***	0.36***	0.38***	0.38***	0.43***	0.09***	0.41***	0.45***
Increases efforts 2	0.27***	0.48***	0.73***		0.33***	0.39***	0.37***	0.40***	0.38***	0.44***	0.08***	0.40***	0.44***
Positive humans 1	0.50***	0.48***	0.39***	0.40***		0.66***	0.61***	0.59***	0.45***	0.53***	0.14***	0.34***	0.35***
Positive humans 2	0.54***	0.50***	0.46***	0.47***	0.76***		0.45***	0.49***	0.36***	0.45***	0.13***	0.29***	0.30***
Positive nature 1	0.47***	0.49***	0.41***	0.42***	0.69***	0.54***		0.69***	0.51***	0.64***	0.14***	0.37***	0.36***
Positive nature 2	0.50***	0.48***	0.45***	0.45***	0.64***	0.54***	0.72***		0.50***	0.66***	0.15***	0.39***	0.41***
In line with nature 1	0.42***	0.50***	0.43***	0.41***	0.57***	0.45***	0.62***	0.60***		0.53***	0.19***	0.34***	0.36***
In line with nature 2	0.43***	0.52***	0.49***	0.51***	0.60***	0.52***	0.68***	0.71***	0.64***		0.18***	0.46***	0.48***
Inexpensive	0.27***	0.24***	0.22***	0.20***	0.31***	0.25***	0.29***	0.32***	0.35***	0.36***		0.14***	0.16***
Equal effects 1	0.32***	0.43***	0.48***	0.48***	0.44***	0.38***	0.47***	0.51***	0.50***	0.58***	0.27***		0.79***
Equal effects 2	0.32***	0.44***	0.50***	0.50***	0.46***	0.38***	0.47***	0.53***	0.48***	0.60***	0.29***	0.83***	

Note. N_{Students}=4,583. $N_{\text{General Public}}$=2,248. To account for the clustered structure of the data within the 19 and 12 countries, respectively, associations were estimated through generalized estimating equations. Unstandardised coefficients presented. Strong associations are highlighted in orange (i.e. associations ≥ 0.60 for the general public, among whom the associations were comparatively stronger, and associations ≥ 0.50 for the students, among whom the associations were comparatively smaller). * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

Table B5. Associations between belief in global warming and perceptions about SRM among students (above diagonal) and among the general public (below diagonal)

	Belief in global warming	SRM limits global warming	SRM addresses causes of GW	SRM increases mitigation efforts	SRM is positive for humans/ nature	SRM is inexpensive	SRM affects countries equally
Belief in global warming		.14***	.01	.04**	.09***	.02	-.06***
SRM limits global warming	.19***		.34***	.25***	.53***	.18***	.25***
SRM addresses causes of GW	.03	.41***		.44***	.46***	.07***	.34***
SRM increases mitigation efforts	-.03	.30***	.46***		.48***	.08***	.45***
SRM is positive for humans/nature	.12***	.59***	.54***	.55***		.20***	.50***
SRM is inexpensive	.06**	.28***	.21***	.21***	.37***		.14***
SRM affects countries equally	-.04	.35***	.42***	.54***	.61***	.28***	

Note. N_{Students}=4,583. $N_{\text{General Public}}$=2,248. To account for the clustered structure of the data within the 19 and 12 countries, respectively, associations were estimated through generalized estimating equations. Standardised coefficients are presented. All variables were standardised at country level. * $p \leq .05$. ** $p \leq .01$. *** $p \leq .001$.

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