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Public engagement with emerging technologies: Does reflective thinking affect survey responses?

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Daniel P. Carlisle, Pamela M. Feetham
Massey University, New Zealand

Malcolm J. Wright

Massey University, New Zealand; University of South Australia, Australia
Damon A. H. Teagle
University of Southampton, UK

Corresponding author:
Daniel P. Carlisle,
School of Communication, Journalism and Marketing, Massey University, Tennent Drive, Palmerston North 4442, New Zealand.
Email: D.Carlisle@massey.ac.nz

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Abstract

Researchers disagree on the extent that brief survey methods accurately reflect citizens' opinions of unfamiliar scientific concepts. We examine whether encouraging participants to engage in more reflective thinking affects their perceptions of emerging climate technologies. Drawing on dual process theories of reasoning, we apply experimental manipulations to encourage fast, intuitive thinking or slow, reflective thinking when responding to an online survey. Similarities in concept evaluation time between the Control and the Intuitive treatment groups indicates that citizens default to fast intuitive judgements to form opinions. However, despite a successful manipulation check, the reflective treatment group did not show any substantively different results. Therefore, encouraging additional thinking is unlikely to shift public perceptions. Post-hoc analysis suggests participants with stronger views may nonetheless take more time to consider their response, without prompting. These findings support the validity of surveys as a method for eliciting stable and meaningful public perceptions of emerging technologies.

Key words: public engagement, survey research, dual process theory, emerging technologies, climate engineering.

1 Introduction

Self-administered questionnaires are a common tool for eliciting public opinion on a large scale. They are potentially helpful for gauging citizens' responses to unfamiliar scientific concepts, such as the emerging climate technologies 'carbon dioxide removal' (CDR) and 'solar radiation management' (SRM)[1] that some scientists believe may be necessary to avoid the worst impacts of climate change (Caldeira and Keith, 2010; MacMartin et al., 2018).

Previous research found that public awareness of CDR and SRM technologies was relatively low and perceptions broadly negative, although more so for SRM than CDR (Carlisle et al., 2020; Cummings et al., 2017). Thus, if global warming mitigation efforts prove insufficient, and should CDR or SRM climate responses be required, emergent public concern may hinder their development and deployment. However, as most citizens will be unfamiliar with such emerging technologies, there is concern about the extent that survey respondents can give meaningful evaluations without first thoroughly reflecting on the technologies in question. What remains unclear is whether researchers can encourage survey participants to engage in more reflective information processing, and if so, whether their responses differ as a result. The current research uniquely addresses this knowledge gap by exploring the extent that encouraging slow, reflective thinking affects survey participants' evaluations of emerging technologies.

[1] Carbon dioxide removal (CDR) approaches extract and sequester carbon from the atmosphere to offset greenhouse gas emissions whereas solar radiation management (SRM) approaches reflect a portion of sunlight away from the Earth to counteract rising temperatures. Collectively these technologies are sometimes referred to as 'climate engineering'.

2 Dual-process theory and public engagement

Dual-process theories offer a useful framework for examining the impact of reflective thinking on citizen evaluations of emerging technologies. Developed in cognitive psychology and behavioural economics, dual process theories posit that human reasoning occurs through two distinct types of information processing, referred to as Type 1 and Type 2 processes (Evans, 2011). Most decision making relies on Type 1 processes that correlate with fast, intuitive thinking to conserve cognitive resources. Type 2 processes correlate with slower, reflective reasoning that can override initial Type 1 reactions but require substantially more cognitive effort (Kahneman, 2011; Evans and Stanovich, 2013; Evans, 2003). Accordingly, since survey respondents have limited time and motivation, they are likely to rely predominantly on Type 1 rather than Type 2 thinking.

Type 1 and Type 2 reasoning can cause individuals to arrive at different conclusions during decision making tasks (Evans and Stanovich, 2013), suggesting that encouraging survey respondents to engage in reflective thinking could affect their survey responses. For example, one study found mixed evidence that respondents who spent more time considering information about climate engineering technologies were comparatively more negative in their overall evaluations (Feetham, 2016). Other studies found that reflective thinkers[2] demonstrated lower acceptance of climate engineering technologies (Braun et al., 2018a) and, in some instances, hold more stable preferences over time (Braun et al., 2018b). Notably, these studies draw their conclusions from correlations rather than establishing causation

[2] Reflective thinking was measured using the Cognitive Reflection Test; a tool for measuring an individuals' disposition for reflective thinking (Frederick, 2005).

through experimental tests, and therefore, it is unclear whether reflective thinking causes more concern, or whether more concern causes greater reflection.

To advance the debate, the present research tests the extent that intuitive Type 1, and reflective Type 2 thinking influence perceptions of CDR and SRM technologies. The current study draws on a quantitative technique (Carlisle et al., 2020; Wright et al., 2014) to measure public opinion of six CDR and SRM technologies. We introduce additional experimental treatments to encourage either fast, intuitive Type 1 or slower, reflective Type 2 thinking (Evans and Stanovich, 2013; Konopka et al., 2019) to determine *whether reflective thinking affects participants' evaluations of CDR and SRM techniques*. A further post-hoc comparison considers whether evaluations change by the time taken to reflect on relevant portions of the survey (Feetham, 2016; Konopka et al., 2019). Consideration of results from the experimental manipulation with those of the post-hoc comparison cast light on *the direction of causation between reflective Type 2 thinking and changes in evaluations*. The research makes a novel contribution by applying dual-process theories to survey-based public engagement research and presents practical implications for researchers conducting meaningful public engagement on mitigation of global warming.

3 Method

Using a large quantitative survey (n = 1558) we measure public perceptions by presenting participants with information about CDR and SRM technologies and analysing the attributes (e.g. *risky* or *environmentally friendly*) that are brought to mind (Carlisle et al., 2020; Wright et al., 2014). The method draws on associative network theories of memory (Anderson and

Bower, 1973) as well as techniques developed by branding experts to model mental associations with a brand or product (Romaniuk, 2013; Wright et al., 2014).

We apply split-sample experimental treatments to encourage either rapid, intuitive Type 1 thinking (n = 434) or slower, reflective Type 2 thinking (n = 373), as well as a Control treatment (n = 751). Finally, we use statistical techniques to establish whether the Type 1 or Type 2 manipulations influence participant responses to the survey. That is, whether reflective thinking affects participant evaluations of CDR and SRM techniques.

3.1 Materials

The questionnaire begins with a general introduction on the topic of global warming, three warmup questions, and further information on potential responses to climate change. Next, participants evaluate three CDR technologies and three SRM technologies individually. These are bioenergy with carbon capture and storage (BECCS), direct air capture and carbon storage (DACCS), enhanced weathering (EW), marine cloud brightening (MCB), mirrors in space (MIS), and stratospheric aerosol injection (SAI)[3]. Since participants are unlikely to have prior knowledge of CDR and SRM technologies we provide a visual diagram and short description for each technology in separate concept evaluation blocks (*Supplementary figure 3*).

[3] BECCS involves the combustion of bioenergy crops to produce renewable energy. The resulting carbon emissions are captured and stored. DACCS uses artificial structures to filter and store carbon dioxide from the atmosphere. EW involves spreading finely ground minerals to accelerate a chemical reaction that draws down carbon from the atmosphere. MCB involves spraying seawater into low clouds to increase their albedo and reflect incoming solar radiation. MIS involves placing reflective materials in orbit to reduce incoming solar radiation. SAI involves spreading sulphate particles into the stratosphere to reflect a portion of incoming solar radiation.

The primary data is derived from the attribute selection task used to measure memory associations with the six technologies (Carlisle et al., 2020; Wright et al., 2014). Following each concept description, participants are asked to select attributes from a pre-determined list that they associate with each technology (*unknown effects, unpredictable, risky, artificial, quick-fix, eyesore, understandable, controllable, environmentally friendly, beneficial, long-term sustainability,* and *cost-effective;* see *supplementary figures 4-6*). Additional Likert-style questions are used to assess respondents understanding of the technology, support for small scale trials, and belief that each technology would help address global warming. Finally, participants answer some general questions about their prior awareness of the technologies, and demographic characteristics. To enable replication and transparency, we provide a more detailed account of the materials, methods, and measures in the online supplementary materials.

3.2 Experimental Manipulations

For the experimental treatments we draw on manipulations developed in previous dual process research, designed to enhance or suppress Type 2 processes via direct instruction (Evans and Stanovich, 2013). Participants in the *Control* treatment proceed through the questionnaire with no further additions or manipulations. In the *Type 1* treatment, participants are forced to rely on fast, Type 1 thinking by using time pressure to inhibit slower Type 2 thinking (Evans and Curtis-Holmes, 2005; Konopka et al., 2019; Evans and Stanovich, 2013). In the *Type 2* treatment, reflective thinking is encouraged by motivating and instructing respondents (Evans and Stanovich, 2013) to read each description thoroughly and to expect their knowledge to be tested. Below are examples of the instructions given to participants in the *Type 1* and *Type 2* treatments both before and during each concept evaluation (see also *supplementary figures 2, 5,* and *6*):

Type 1: **"***It is important to* ***make your decisions quickly****. Please do not spend much time evaluating choices before you tick the boxes."*

Type 2: *"At the end of each section you will be asked a random question about the description you have just read. You will* ***not*** *be able to go back to check, so it is important that you* ***read each description thoroughly****."*

On a new page, following each concept evaluation, participants in the *Type 2* treatment are also asked a multi-choice quiz item based on the concept they had just evaluated (*supplementary figure 7*).

A further comparison of Type 1 versus Type 2 thinking is available by considering time taken to complete the task for each concept block (Feetham, 2016; Konopka et al., 2019). In this case, quicker respondents are assumed to engage predominantly in intuitive Type 1 thinking, and slower respondents to engage in relatively more reflective Type 2 thinking. Categorising respondents by time taken is found to give similar results to other manipulations of Type 1 and Type 2 thinking (Konopka et al., 2019)

3.3 Sample

UK participants (n = 1558) were recruited online using a commercial panel provider; Dynata (https://www.dynata.com) in 2018, with panel members recruited via topic-blind survey invitations until demographic quotas are met and allocated to one of three treatments; *Control*, *Type 1*, or *Type 2*. Overall, the sample characteristics show a satisfactory spread of demographics with an even gender split (50% male and female) and a mean age of 52 (SD = 17). *Supplementary Table 1* outlines the full demographic breakdown.

4 Results

4.1 Type 1 and Type 2 Manipulations

The success of the primary experimental manipulations is measured using timers for the duration of the participant interaction with the concept evaluation block.

Table 1 | Concept evaluation time by treatment

Treatment	Mean	Standard Deviation	Mean (5% Trimmed)
Type 1	4 min 53 s	3 min 50 s	4 min 28 s
Control	6 min 00 s	12 min 17 s	4 min 52 s
Type 2	7 min 17 s	8 min 6 s	6 min 26 s

Comparisons of the concept evaluation times (Table 1) indicate the manipulations successfully encouraged participants in the slow Type 2 treatment to reflect on the information for approximately two minutes longer than the Type 1 treatment (based on the 5% trimmed mean). Statistical tests ($\chi^2(2) = 47.887$, $p < 0.001$) confirm participants in the Type 2 treatment group take significantly longer than participants in the Type 1 treatment ($p < 0.001$) and the Control treatment ($p < 0.001$). However, there was no significant differences in time-taken between the Type 1 and Control treatments ($p = 0.305$).

A likely explanation for the non-significant differences between the Type 1 and Control is that participants in the Control treatment automatically default to fast Type 1 thinking and therefore take a similar amount of time to evaluate concepts as the Type 1 treatment. This conclusion aligns with dual processing theories that suggest Type 1 processes are the default form of human reasoning (Kahneman and Frederick, 2002; Evans, 2007; Evans and Stanovich, 2013) and with more general observations that survey mechanisms by default tend to elicit fast-intuitive, rather than slow-reflective responses (Wright et al., 2014).

Thus, it is not surprising there are no substantial differences in concept evaluation time between the Type 1 and Control treatments.

4.2 Awareness and Understanding

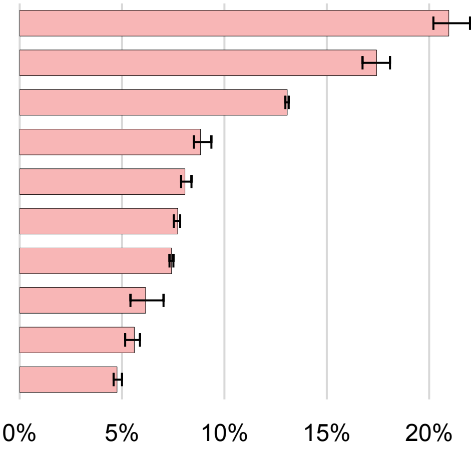
Few participants (19%) report prior knowledge of the CDR and SRM proposals across the three treatment groups (see also, Carlisle et al., 2020; Cummings et al., 2017) indicating most rely on the information provided to inform their evaluations. To check the adequacy and understanding of these concept materials we ask whether participants believe they can explain each concept to somebody else. Responses are acceptable with 44% of participants across the three treatments agreeing (ranging from 38% - 48% between technologies), 37% neutral, and only 19% disagreeing. Further analysis (see supplementary materials) indicates no significant differences in mean understanding scores between treatments ($F_{(.05, 2, 1555)} = 0.95$, $p = 0.39$).

4.3 Attribute Popularity (Salience)

To assess whether *reflective Type 2 thinking changes participant evaluations of CDR and SRM techniques* we compare differences in attribute popularity (salience) between treatments. Attribute salience is measured as each attributes' percentage share of the total associations (Table 2). In line with previous research (Carlisle et al., 2020; Wright et al., 2014) the negative attributes *unknown effects, risky,* and *artificial* rank the highest by popularity and account for over 50% of the total attribute associations.

Table 2 | Attribute popularity (salience) for CDR and SRM approaches, as % of associations

Rank	Attribute	Type 1	Control	Type 2	Mean (Error bars show range between treatments)
1	Unknown effects	21	22	20	
2	Risky	17	17	18	
3	Artificial	13	13	13	
4	Understandable	9	9	9	
5	Environmentally friendly	8	8	8	
6	Controllable	8	8	8	
7	Long-term sustainability	7	7	8	
8	Quick-fix	7	6	5	
9	Eyesore	6	5	6	
10	Cost effective	5	5	5	



The percentage shares of associations show little variation between treatments with no more than one percentage point deviation from the overall mean (see error bars, Table 2) and correlations between treatments of no less than $r = 0.99$. Likewise, when the data is split by CDR and SRM technologies, the treatments retain minimal variation with correlations of no less than $r = 0.96$ (see *supplementary tables 7 & 8)*. Thus, there is no evidence to suggest that reflective Type 2 thinking affects the salience or retrieval of certain attributes in memory.

Attribute associations are also aggregated to give an overall count of associations per technology and mean count of associations per respondent (Table 3). The data indicate respondents associate approximately two attributes with each technology (mean ranging from 1.9 – 2.2). Aggregating the mean association metric reveals participants in the Type 1 treatment retrieved slightly more attributes, however both ANOVA ($F_{(.05, 2, 1555)} = 1.35$, $p = 0.26$) and a Kruskal-Wallis test ($\chi^2(2) = 1.07$, $p = 0.59$) indicate the differences are non-significant. Thus, there is no evidence to suggest reflective thinking causes respondents to retrieve more information (attribute associations) from memory.

Table 3 | Memory associations for CDR and SRM approaches as counts and % net positive associations

	Bioenergy with Carbon Capture and Storage	Direct Air Capture and Carbon Storage	Enhanced Weathering	Marine Cloud Brightening	Mirrors in Space	Stratospheric Aerosol Injection	Total
Count of Associations							
Type 1 (*n* = 434)	953	916	884	892	916	933	5494
Control (*n* = 751)	1529	1513	1537	1449	1527	1507	9062
Type 2 (*n* = 373)	755	764	709	743	769	788	4528
Mean associations per respondent							
Type 1 (*n* = 434)	2.2	2.1	2.0	2.1	2.1	2.1	12.7
Control (*n* = 751)	2.0	2.0	2.0	1.9	2.0	2.0	12.1
Type 2 (*n* = 373)	2.0	2.0	1.9	2.0	2.1	2.1	12.1
Net positive associations							
Type 1 (*n* = 434)	7%	-5%	-15%	-42%	-51%	-55%	-27%
Control (*n* = 751)	4%	-8%	-11%	-39%	-48%	-62%	-27%
Type 2 (*n* = 373)	3%	6%	-18%	-35%	-46%	-62%	-25%

4.4 Concept Evaluations

To compare participants positive (or negative) perceptions of CDR and SRM technologies we calculate a 'net positive' metric as the percentage count of positive associations for each technology less the percentage count of negative associations, presented numerically in Table 3 and graphically in Figure 1.

The net positive metric yields similar findings to previous studies (Carlisle et al., 2020; Wright et al., 2014) with the three SRM techniques perceived more negatively than the three CDR approaches. SAI remains the most negatively perceived approach in all three treatments with negative attributes accounting for over three quarters of the total attribute associations. BECCS remains the most positively perceived approach for the Control and Type 1 treatments with positive attribute associations accounting for over half of the total associations. However, in the Type 2 treatment DACCS surpasses BECCS as the most positively perceived approach, though the other four technologies retain the same rank order.

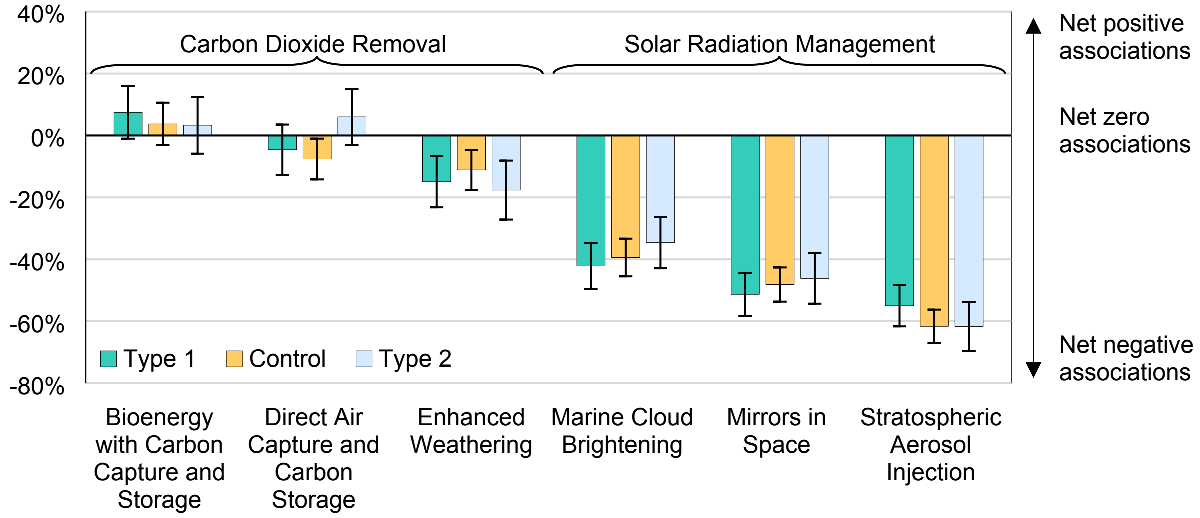


Figure 1 | *Net memory associations for climate technologies. Public perceptions of SRM remain more negative than CDR and are relatively unaffected by Type 1 and Type 2 manipulations. Error bars show 95% Confidence Intervals.*

To establish whether the minor differences between groups are significant, we conduct ANOVA for the CDR and SRM net positive associations variables between treatments. ANOVA reveals the differences in net positive associations between treatments are non-significant for both CDR ($F_{(.05, 2, 1555)} = 0.19$, $p = 0.83$) and SRM ($F_{(.05, 2, 1555)} = 0.32$, $p = 0.73$). Thus, we find no evidence to suggest Type 2 thinking affects participants' positive (or negative) perceptions of CDR and SRM technologies.

4.5 Response Time

Within each treatment, participants differ substantially in their concept evaluation time, suggesting reflective thinking could vary by participant. Since Type 1 thinking correlates with fast, automatic responding and Type 2 thinking correlates with slow, reflective responding (Evans and Stanovich, 2013) we follow Feetham (2016) and Konopka et al.

(2019) in treating time taken for concept evaluation as a proxy for reflection – that is, as a further post-hoc comparison of Type 1 and Type 2 thinking.

Scatter plots reveal heteroscedasticity and some extreme values for the concept evaluation time variable. Accordingly, we exclude sixteen outliers across the three treatments using Mahalanobis distance and use Kendall Tau-b non-parametric correlations to compare concept evaluation times (Table 4). As a further robustness check, we replicate the correlational analysis using three further samples from the United States (n = 746), Australia (n = 763), and New Zealand (n = 729) collected at the same time with the same questionnaire format as the UK Control treatment.

Across the three UK treatments and three additional countries, there are significant but small ($r < 0.30$) negative correlations between concept evaluation time and SRM net positive associations. These results indicate that participants who spent more time considering the information were also more negative toward SRM. Smaller negative correlations are also detected between concept evaluation time and the CDR net positive variable in the United States, Australia and New Zealand. This provides some evidence that reflective Type 2 thinking is associated with stronger (in this case more negative) views. However, as this evidence was only found in the post-hoc comparison, and not the experimental manipulations, the results suggest that those with strong views are somewhat likely to engage in more reflective thinking, rather than reflective thinking causing stronger views.

Table 4 | Correlations with Net Positive and Concept Evaluation Time Variables

	Test Statistic	Test Statistic Value	P value	Bonferroni-corrected critical P value
Type 1 (UK) Treatment				
Carbon Dioxide Removal	$\mathbf{r}_{\tau(431)}$	-0.055	0.099	0.025
Solar Radiation Management	$\mathbf{r}_{\tau(431)}$	-0.249	0.000	0.025
Control (UK) Treatment				
Carbon Dioxide Removal	$\mathbf{r}_{\tau(745)}$	-0.057	0.025	0.025
Solar Radiation Management	$\mathbf{r}_{\tau(745)}$	-0.291	0.000	0.025
Type 2 (UK) Treatment				
Carbon Dioxide Removal	$\mathbf{r}_{\tau(370)}$	-0.073	0.042	0.025
Solar Radiation Management	$\mathbf{r}_{\tau(370)}$	-0.281	0.000	0.025
US Sample				
Carbon Dioxide Removal	$\mathbf{r}_{\tau(732)}$	-0.090	0.000	0.025
Solar Radiation Management	$\mathbf{r}_{\tau(732)}$	-0.279	0.000	0.025
AU Sample				
Carbon Dioxide Removal	$\mathbf{r}_{\tau(762)}$	-0.096	0.000	0.025
Solar Radiation Management	$\mathbf{r}_{\tau(762)}$	-0.264	0.000	0.025
NZ Sample				
Carbon Dioxide Removal	$\mathbf{r}_{\tau(708)}$	-0.068	0.008	0.025
Solar Radiation Management	$\mathbf{r}_{\tau(708)}$	-0.188	0.000	0.025

5 Discussion

Some researchers have voiced concerns that quantitative surveys may not accurately reflect public perceptions of unfamiliar technologies as participants have only a short period to form an opinion on limited information (Merk et al., 2019). Contrary to this concern, our research indicates that participants are not forced to engage in fast, limited information processing, but rather, they choose to. Our study finds no significant difference in concept evaluation times between the Type 1 treatment (who were encouraged not to spend long thinking about their response) and the Control treatment (who received no specific instructions). Conversely the Type 2 treatment (who were encouraged to read each description thoroughly and told they would be tested on their knowledge) took significantly longer in the concept evaluation task. The non-significant differences between the Type 1 and Control treatments suggest that most citizens rely on fast intuitive thinking by default to evaluate emerging climate technologies, rather than slow, reflective thinking. Thus, eliciting fast, intuitive responses with traditional survey methods may not threaten external validity after all. Rather, survey responses may use the same fast, intuitive information processing that the broader public rely on to form opinions on emerging technologies.

Additionally, we find little evidence to suggest that encouraging reflective thinking impacts public perceptions of CDR and SRM techniques. Though the experimental manipulation successfully encouraged participants to spend more time reflecting on the information provided, our statistical analyses found no significant effect on participants' perceptions of CDR or SRM. Conversely, respondents who show higher concern toward emerging technologies may engage in more reflective thinking without prompting. Accordingly, our findings suggest there is little for public engagement researchers to gain from actively encouraging reflective thinking during survey research.

In line with dual-process theories (Kahneman and Frederick, 2002; Evans, 2007; Evans and Stanovich, 2013) and the low-information rationality model (Scheufele, 2006; Popkin, 1994) these findings suggest that public perception of CDR and SRM is dominated by fast intuitive thinking, rather than slower, reflective reasoning. Accordingly, the public are unlikely to devote substantial time and cognitive effort toward processing detailed information from science communicators. Instead, communications should focus more on salient aspects (e.g. unknown effects, risk, and artificiality for CDR and SRM) that contribute the most to overall public perceptions of emerging climate technologies.

Meanwhile, with the rapid rise in global mean temperature, social scientists urgently need to expand global public engagement efforts and identify the most acceptable pathways for addressing climate change. The current study suggests that, despite concerns about external validity, large scale quantitative methods remain useful tools for consulting citizens worldwide on emerging climate technologies. With the continued worldwide inaction on global emissions, researchers must move quickly to provide a representative voice for the global public and ensure citizens' concerns are heard. One effective way of doing so is to use the techniques developed from memory association theory to systematically measure public perceptions through online surveys.

5.1 Limitations and Future Directions

The findings above apply to public engagement research within the context of self-administered surveys. Future research could investigate whether reflective thinking has a similarly negligible impact on public perceptions during deliberative methods of public engagement that purportedly elicit more considered responses compared to traditional survey methods (Macnaghten and Szerszynski, 2013).

6 Declaration of competing interests

The authors declare that there is no conflict of interest.

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Supplementary information

This supplementary information provides details that are omitted from the main manuscript and is divided into nine sections:

[*Information about prior publication of the datasets are redacted here for anonymity during the review process. This will be amended to a reference prior to publication should the manuscript be accepted.]*

1 Survey Materials

Prior to beginning the survey, participants read an information sheet and indicate their consent by proceeding. The questionnaire begins with the survey introduction and warmup questions (*Supplementary Figure 1*), followed by the concept introductions, including instructions specific to each experimental treatment (*Supplementary Figure 2*).

Next, participants evaluate each of the three CDR technologies and three SRM technologies individually, in a randomised order. Since participants are unlikely to have prior knowledge of CDR and SRM technologies we provide a visual diagram and short description for each technology (*Supplementary Figure 3*). The concept imagery and descriptions are carefully designed using matching criteria for colour, scale, content, and length (93-100 words). Based on the concept materials for each technology, participants are asked to select attributes from a list, using a free choice, pick any format (Romaniuk, 2013) that they associate with each technology (*Supplementary Figure 4*). The list contains attributes generated in previous studies (reference redacted for review) using qualitative depth interviews in 2012 (n = 30) and 2018 (n = 15) that citizens associate with, or use to differentiate between, the six technologies. The presentation order of concepts and attributes are randomised to reduce order effects. Participants receive additional instructions in the Type 1 (*Supplementary Figure 5*) and Type 2 (*Supplementary Figure 6*) experimental treatments. The concept evaluation block also includes three further items to measure perceived technological feasibility, support for small scale trials, and participant understanding.

Following each concept evaluation block, participants in the Type 2 treatment are also asked a brief, multichoice quiz question about each of the concept descriptions they read (*Supplementary Figure 7*). The presentation order of the possible quiz answers is randomised, and participants are unable to return to the previous page to check their answer.

The survey concludes with items to measure prior awareness ("Did you know about any of these proposals before you began this survey?" – Yes/No), ecological views, and sample demographics (*Supplementary Table 1*).

Supplementary Figure 1 | Survey introduction and warmup questions

Global warming refers to the idea that the world's average temperature has been increasing, may increase more in the future, and is causing changes to the world's climate. These changes have been attributed to increasing greenhouse gas emissions such as carbon dioxide.

Please read the statements below and then indicate whether you agree or disagree by clicking
ONE button beside each statement

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Don't know
We should try to reduce global warming.	○	○	○	○	○	○
Global warming is causing changes to the climate.	○	○	○	○	○	○
Humans are primarily responsible for global warming.	○	○	○	○	○	○

→

Supplementary Figure 2 | Concept introductions

Control treatment

In response to global warming, 196 countries adopted the 2015 Paris Agreement under the United Nations Framework Convention on Climate Change. The aim of the agreement is to limit the global increase in temperatures to below 2° Celsius.

Alongside ways for adapting to global warming, governments and scientists are considering a range of possible solutions for achieving the 2°C goal. Some proposals include reducing global emissions, removing carbon dioxide from the air, or reflecting sunlight back into space.

We would like to know what you think about some of these proposals for removing carbon dioxide and reflecting sunlight. In the following pages we will present six proposals and ask some questions about each one. Please read the description and tick the boxes that you think apply. There are no right or wrong answers in this survey. Rather we are interested in your opinion.

→

Type 1 treatment

In response to global warming, 196 countries adopted the 2015 Paris Agreement under the United Nations Framework Convention on Climate Change. The aim of the agreement is to limit the global increase in temperatures to below 2° Celsius.

Alongside ways for adapting to global warming, governments and scientists are considering a range of possible solutions for achieving the 2°C goal. Some proposals include reducing global emissions, removing carbon dioxide from the air, or reflecting sunlight back into space.

We would like to know what you think about some of these proposals for removing carbon dioxide and reflecting sunlight. In the following pages we will present six proposals and ask some questions about each one. Please read the description and tick the boxes that you think apply. There are no right or wrong answers in this survey. Rather we are interested in your opinion.

It is important to ***make your decisions quickly.*** *Please do not spend much time evaluating choices before you tick the boxes.*

→

Type 2 treatment

In response to global warming, 196 countries adopted the 2015 Paris Agreement under the United Nations Framework Convention on Climate Change. The aim of the agreement is to limit the global increase in temperatures to below 2° Celsius.

Alongside strategies for adapting to global warming, governments and scientists are considering a range of possible solutions for achieving the 2°C goal. Some proposals include reducing global emissions, removing carbon dioxide from the air, or reflecting sunlight back into space.

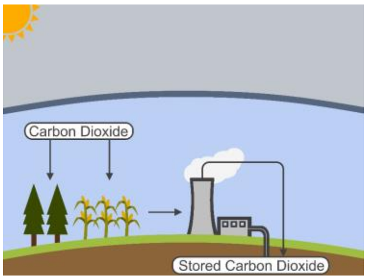
We would like to know what you think about some of these proposals for removing carbon dioxide and reflecting sunlight. In the following pages we will present six proposals and ask some questions about each one. Please read the description and tick the boxes that you think apply. There are no right or wrong answers in this survey. Rather we are interested in your opinion.

At the end of each section you will be asked a random question about the description you have just read. You will ***not*** *be able to go back to check, so it is important that you* ***read each description thoroughly.***

→

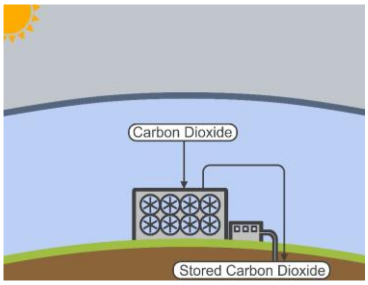
Supplementary Figure 3 | Concept Boards

Bio-Energy with Carbon Capture and Storage (BECCS)



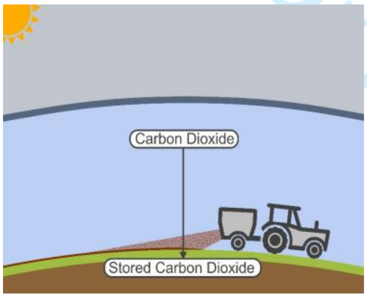
Bio-energy with Carbon Capture and Storage (BECCS) involves growing plants or 'biomass' to remove carbon dioxide from the air. The biomass is combusted to produce renewable energy. The emitted carbon dioxide is captured and stored indefinitely in underground reservoirs. Producing biomass, building infrastructure, and transporting carbon incur costs. The land requirements for BECCS could affect food production, biodiversity, water allocation, and deforestation. Producing and transporting biomass require renewable energy sources to ensure that more carbon dioxide is stored than emitted. BECCS could be introduced gradually, however, large-scale implementation and infrastructure is required to reduce global temperatures.

Direct Air Capture and Carbon Storage (DACCS)



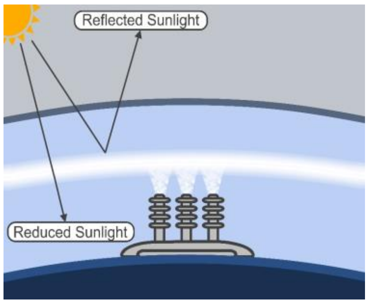
Direct Air Capture and Carbon Storage (DACCS) involves building structures that filter carbon dioxide from the air. Carbon dioxide is captured, transported, and stored indefinitely in underground reservoirs. Structures can be located anywhere and would target areas with suitable underground reservoirs. Building and operating air capture structures requires land and incurs costs. Powering the air capture structures and transporting carbon dioxide requires renewable energy sources to ensure that more carbon is stored than emitted. Direct Air Capture could be introduced gradually, however, large-scale implementation and infrastructure are required to reduce global temperatures.

Enhanced Weathering



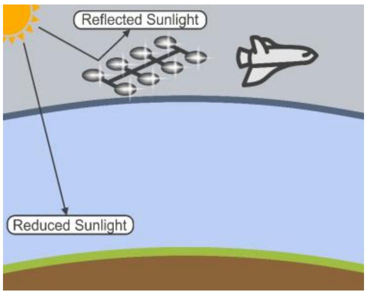
Certain rocks react with atmospheric carbon dioxide to break down or 'weather'. This reaction forms new minerals that store carbon indefinitely. Crushing and spreading the rocks accelerates carbon dioxide removal, improves soil quality, may reduce mine wastes, and could reduce ocean acidification if washed out to sea. Enhanced Weathering requires land and could affect biodiversity, human health, and leach heavy metals into soils. Mining, transporting, and spreading rocks incur costs and require renewable energy sources to ensure that more carbon is stored than emitted. Enhanced Weathering could be introduced gradually, however, large-scale implementation is required to reduce global temperatures.

Marine Cloud Brightening



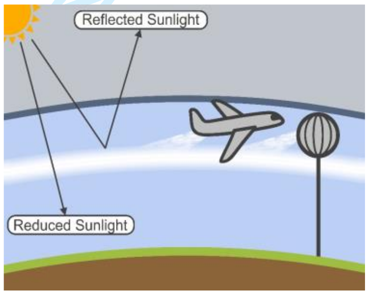
Marine Cloud Brightening involves automated ships spraying small seawater droplets above the ocean in targeted areas. Vapour forms around these droplets, increasing the number and brightness of clouds reflecting some sunlight back into space. Developing and building fleets of spraying vessels incurs costs. Cloud brightening is restricted to marine areas and may alter local rainfall patterns. Changes in light, ocean temperature, and currents may affect marine nutrient growth. Large-scale implementation and continuous applications are required to maintain the cooling effect. Temperatures would quickly revert to pre-application levels if stopped. Implementation may require international agreements.

Mirrors in Space



Mirrors in Space involves positioning reflective structures to orbit the Earth. These structures intercept and reflect some sunlight back into space, rapidly cooling the Earth. Space-craft would be used to position the materials. Space transportation incurs costs and would require large-scale investment, research, and development. Implementation would increase the number of orbital objects and could produce an uneven cooling effect, alter rainfall patterns, and change the appearance of the night sky. Large-scale implementation is required and temperatures would revert to pre-application levels if the structures were removed. Implementation would take decades and may require international agreements.

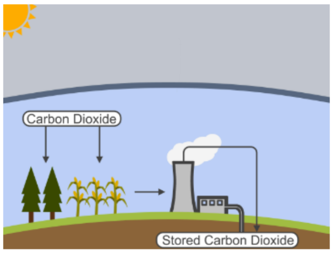
Stratospheric Aerosol Injection



Stratospheric Aerosol Injection involves spreading tiny reflective particles into the stratosphere. The particles reflect some sunlight back into space, rapidly cooling the whole Earth. Sulphate aerosols could be spread using aeroplanes or large balloons tethered to lightweight pipes. Building fleets of aeroplanes or balloons incurs costs. Stratospheric aerosols would make the sky whiter and could affect the ozone layer, rainfall patterns and crop yields. Environmental and local impacts are poorly understood. Large-scale implementation and continuous applications are required to maintain the cooling effect. Temperatures would quickly revert to pre-application levels if stopped. Implementation may require international agreements.

Supplementary Figure 4 | Concept evaluation block – Control treatment

Bio-Energy with Carbon Capture and Storage (BECCS)



Bio-energy with Carbon Capture and Storage (BECCS) involves growing plants or 'biomass' to remove carbon dioxide from the air. The biomass is combusted to produce renewable energy. The emitted carbon dioxide is captured and stored indefinitely in underground reservoirs. Producing biomass, building infrastructure, and transporting carbon incur costs. The land requirements for BECCS could affect food production, biodiversity, water allocation, and deforestation. Producing and transporting biomass require renewable energy sources to ensure that more carbon dioxide is stored than emitted. BECCS could be introduced gradually, however, large-scale implementation and infrastructure is required to reduce global temperatures.

Which of the descriptors in the list below do you think applies to BECCS? Please select as many as apply.

Environmentally Friendly	Controllable
Unknown Effects	Beneficial
Eyesore	Quick-Fix
Understandable	Risky
Artificial	Long-Term Sustainability
Cost Effective	Unpredictable

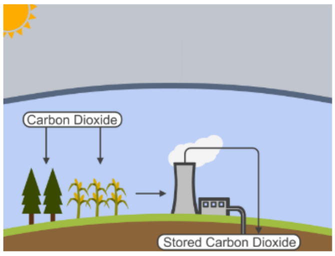
Please read the statements below and indicate whether you agree or disagree by clicking ONE button beside each statement.

	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
I would support small-scale trials of **Bio-energy with Carbon Capture and Storage** .	○	○	○	○	○
After reading the description I think that I could explain **Bio-energy with Carbon Capture and Storage** to somebody else.	○	○	○	○	○
I think **Bio-energy with Carbon Capture and Storage** would help reduce global warming.	○	○	○	○	○

→

Supplementary Figure 5 | Concept evaluation block – Type 1 treatment

Bio-Energy with Carbon Capture and Storage (BECCS)



Bio-energy with Carbon Capture and Storage (BECCS) involves growing plants or 'biomass' to remove carbon dioxide from the air. The biomass is combusted to produce renewable energy. The emitted carbon dioxide is captured and stored indefinitely in underground reservoirs. Producing biomass, building infrastructure, and transporting carbon incur costs. The land requirements for BECCS could affect food production, biodiversity, water allocation, and deforestation. Producing and transporting biomass require renewable energy sources to ensure that more carbon dioxide is stored than emitted. BECCS could be introduced gradually, however, large-scale implementation and infrastructure is required to reduce global temperatures.

Once again I would like to remind you to ***make your decisions quickly.***

Which of the descriptors in the list below do you think applies to BECCS? Please select as many as apply.

Beneficial	Long-Term Sustainability
Unknown Effects	Controllable
Risky	Eyesore
Artificial	Cost Effective
Environmentally Friendly	Understandable
Quick-Fix	Unpredictable

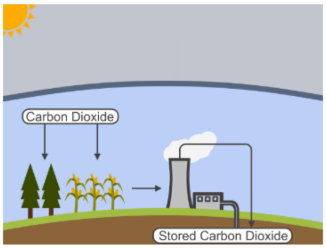
Please read the statements below and indicate whether you agree or disagree by clicking ONE button beside each statement.

	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
I think **Bio-energy with Carbon Capture and Storage** would help reduce global warming.	○	○	○	○	○
I would support small-scale trials of **Bio-energy with Carbon Capture and Storage** .	○	○	○	○	○
After reading the description I think that I could explain **Bio-energy with Carbon Capture and Storage** to somebody else.	○	○	○	○	○

→

Supplementary Figure 6 | Concept evaluation block – Type 2 treatment

Bio-Energy with Carbon Capture and Storage (BECCS)



Bio-energy with Carbon Capture and Storage (BECCS) involves growing plants or 'biomass' to remove carbon dioxide from the air. The biomass is combusted to produce renewable energy. The emitted carbon dioxide is captured and stored indefinitely in underground reservoirs. Producing biomass, building infrastructure, and transporting carbon incur costs. The land requirements for BECCS could affect food production, biodiversity, water allocation, and deforestation. Producing and transporting biomass require renewable energy sources to ensure that more carbon dioxide is stored than emitted. BECCS could be introduced gradually, however, large-scale implementation and infrastructure is required to reduce global temperatures.

*Once again, I would like to remind you to **read the description thoroughly**. You will be asked a random question about this description later in this survey and you will **not** be able to return to this page.*

Which of the descriptors in the list below do you think applies to BECCS?
Please select as many as apply.

Understandable	Environmentally Friendly
Risky	Unknown Effects
Cost Effective	Long-Term Sustainability
Beneficial	Unpredictable
Controllable	Eyesore
Artificial	Quick-Fix

Please read the statements below and indicate whether you agree or disagree by clicking ONE button beside each statement.

	Strongly agree	Agree	Neutral	Disagree	Strongly Disagree
I think **Bio-energy with Carbon Capture and Storage** would help reduce global warming.	○	○	○	○	○
After reading the description I think that I could explain **Bio-energy with Carbon Capture and Storage** to somebody else.	○	○	○	○	○
I would support small-scale trials of **Bio-energy with Carbon Capture and Storage** .	○	○	○	○	○

→

Supplementary Figure 7 | Quiz questions – Type 2 treatment

Bio-energy with carbon capture and storage

On the previous page, you read a description of **Bio-Energy with Carbon Capture and Storage**.

According to the description, what happens to the Biomass once it is grown?

Please select the most correct answer.

- The biomass is buried to store the carbon underground.
- The biomass is combusted to produce renewable energy.
- The biomass is fermented to produce biofuel.

→

Mirrors in space

On the previous page, you read a description of **Mirrors in Space**.

According to the description, what would implementation involve?

Please select the most correct answer.

- Implementation could be achieved quickly but may require international agreements.
- Implementation would take decades and may require international agreements.
- Implementation would be inexpensive and would not require international agreements.

→

Marine cloud brightening

On the previous page, you read a description of **Marine Cloud Brightening**.

According to the description, what does Marine Cloud Brightening involve?

Please select the most correct answer.

- Marine Cloud Brightening involves naval ships spraying large seawater droplets into the stratosphere.
- Marine Cloud Brightening involves long hoses spraying small seawater droplets above the land in coastal areas.
- Marine Cloud Brightening involves automated ships spraying small seawater droplets above the ocean in targeted areas.

→

Enhanced weathering

On the previous page, you read a description of **Enhanced Weathering**.

According to the description, how would Enhanced Weathering be implemented?

Please select the most correct answer.

- Enhanced Weathering could be introduced internationally, and large-scale implementation would rapidly reduce global temperatures
- Enhanced Weathering could be introduced rapidly, and small-scale implementation would reduce global temperatures.
- Enhanced Weathering could be introduced gradually, however, large-scale implementation is required to reduce global temperatures.

→

Direct air capture and carbon storage

On the previous page, you read a description of **Direct Air Capture and Carbon Storage**.

According to the description, where could the air capture structures be located?

Please select the most correct answer.

- Structures can be located anywhere and would target areas with high carbon dioxide levels.
- Structures can be located in specific areas away from towns or cities.
- Structures can be located anywhere and would target areas with suitable underground reservoirs.

→

Stratospheric aerosol injection

On the previous page, you read a description of **Stratospheric Aerosol Injection.**

According to the description, what would implementation involve involve?

Please select the most correct answer.

- Large-scale implementation and a one-off application is required to maintain the cooling effect. Temperatures would eventually revert to pre-application levels if stopped.
- Large-scale implementation and continuous applications are required to maintain the cooling effect. Temperatures would quickly revert to pre-application levels if stopped.
- Large-scale implementation and continuous applications are required to achieve the cooling effect. Temperatures would remain constant if applications were stopped.

→

2 Sample Demographics

Supplementary Table 1 | Sample Demographics

	Type 1 Group (n=434)	Control Group (n=751)	Type 2 Group (n=373)	UK Census[1,2]
Age (Years)*	%	%	%	%
18 - 24	4	3	6	13
25 - 34	14	16	13	18
35 - 44	17	19	19	19
45 - 54	18	17	17	19
55 - 64	19	18	17	16
65 - 74	16	15	17	12
75 - 80	14	13	12	5
Gender				
Male	50	50	49	49
Female	50	50	51	51
	Type 1 Group (n=434)	**Control Group (n=751)**	**Type 2 Group (n=373)**	**Office for National Statistics (2018)[3]**
Household Annual Income				
Less than £12,999	3	5	5	6
£13,000-£18,999	11	11	10	11
£19,000-£25,999	15	9	11	16
£26,000-£31,999	17	14	12	13
£32,000-£47,999	14	15	11	26
£48,000-£63,999	19	23	25	13
£64,000-£95,999	11	11	12	11
More than £96,000	8	7	9	5
	Type 1 Group (n=434)	**Control Group (n=751)**	**Type 2 Group (n=373)**	**YouGov (Nov, 2018)[4]**
Political Support**				
Conservative Party	38	43	40	39
Labour Party	39	34	36	36
Liberal Democrats	10	11	11	8
Other/Independent	13	12	13	14
Education***				
Completed Postgraduate (e.g. Masterate or PhD)	9	8	13	
Completed undergraduate (e.g. Bachelor's Degree)	26	27	26	
Some tertiary education (e.g. Certificate or Diploma)	16	17	19	
Trade or Technical Qualification (e.g. Apprenticeship, Industry Qualification, etc.)	14	15	13	
Graduated Secondary School (High School)	32	30	27	
Graduated Primary School (Elementary School)	3	3	2	
Location***				
More than 5 million people (Major Urban Area)	8	8	8	
1 million to 4.9 million people	6	5	6	
100,000 to 999,999 people	21	17	18	
50,000 to 99,999 people	12	16	15	
10,000 to 49,999 people	23	23	23	
1,000 to 9,999 people	20	20	17	
200 to 999 people	5	7	7	
Less than 200 people (Rural Area)	6	4	5	

*Census data for age is calculated as the proportion of the 18 - 80 age group.
**Political support is calculated excluding invalid responses.
***Population data for Education and Location are based on international comparisons rather than on UK census categories, so comparable national statistics are not available. However, the sample shows a satisfactory demographic spread that is consistent between subgroups. Additionally, the univariate and multivariate tests (Supplementary Table 5 and 6) indicate that neither variable has a statistically significant impact on participant responses. Therefore, any differences between the samples and the UK population are unlikely to impact the generalisability of the study.

3 Measures

Concept evaluation time is recorded in seconds and aggregated across the six concepts. Time spent answering the additional quiz items in the Type 2 treatment is excluded.

Comparisons of mean concept evaluation times indicate the manipulations successfully encouraged participants to respond using fast Type 1 processing or slow Type 2 processing (Table 1). Since extreme values can influence the mean statistic, we also report the 5% trimmed mean as an added robustness check. The trimmed mean shows over a 40% difference (1 min 59 s) between the time taken by the Type 1 and Type 2 groups. A non-parametric Kruskal-Wallis test for differences in concept evaluation times reveals a statistically significant difference between treatments ($\chi^2(2) = 47.887$, $p < 0.001$). Post hoc tests show participants in the Type 2 treatment group take significantly longer in the concept evaluation task than participants in the Type 1 treatment ($p < 0.001$) and the control treatment ($p < 0.001$). However, no significant differences are identified between the Type 1 and Control treatments ($p = 0.305$).

Attribute associations are coded as '1 = associated or '0 = not associated' for each attribute-technology combination. Kendal Tau-B nonparametric correlations are used to identify and remove duplicate measures of overlapping memory (attribute) associations that substantially exceed the average (Romaniuk, 2013). As found in (reference redacted for review) the attributes *beneficial* and *unpredictable* exceed the 0.30 threshold proposed by Cohen (1988)[5] to differentiate small and medium effect sizes and are therefore removed from further analysis (*Supplementary Table 3*).

To enable statistical comparisons between treatment groups, a net positive association variable is calculated as the sum of *each* participants' positive associations minus the sum of their negative associations. Net positive variables are aggregated by CDR (M = -0.25, SD = 4.14), SRM (M = -3.01, SD = 3.75), or combined across all six technologies (M = -3.26, SD = 6.49), with 0 representing an equal balance of positive and negative attribute associations. An overall net positive metric is also reported for each treatment (Table 3) and is calculated as the sum of *all* participants' positive associations for each technology, minus their negative associations, converted to an overall percentage. The statistical properties of the net positive variables are examined by treatment group

(*Supplementary Table 4; supplementary figures 8*, *9*, and *10*) and deemed acceptable for further analysis. Univariate and multivariate tests between the *Combined net positive variable* and demographic variables are conducted to identify covariates for the principal analysis. Univariate tests (*Supplementary Table 5*) identify statistically significant relationships between the combined net positive variable and age across all three treatments and political party in the control treatment. However, multivariate analysis including tests for main effects and two-way interactions are non-significant (*Supplementary Table 6*). Therefore, demographic covariates are deemed unnecessary for further statistical tests.

Further questions include participant confidence in their understanding of the stimuli and prior awareness of the technologies. For each technology, participants indicate their confidence in understanding on a five-point Likert-style scale ("after reading the description I think that I could explain [this technology] to somebody else") coded as 1 = Strongly agree and 5 = Strongly disagree. Participants in the *Type 2* treatment were overall slightly more confident in their understanding (M = 2.65, SD = 0.78) than participants in the *Type 1* (M = 2.71, SD = 0.80) or *Control* treatments (M = 2.71, SD = 0.80); however, the differences between treatments are non-significant ($F_{(.05, 2, 1555)} = 0.95$, $p = 0.39$). Following the concept evaluation block participants are asked "Did you know about any of these proposals before you began this survey?". Responses are coded as '1 = yes', '0 = no' (M = 0.19, SD = 0.39).

4 Kendall Tau-b nonparametric correlations test for overlapping mental constructs

Supplementary Table 3 | Kendall Tau-b Nonparametric Correlations (*n*=1558)

	Unk	Unp	Ris	Art	Qui	Eye	Und	Ben	Con	Env	Sus	Cos
Unknown effects		0.34	0.27	0.17	0.00	0.05	-0.13	-0.24	-0.20	-0.21	-0.19	-0.16
Unpredictable*	0.34		0.32	0.20	0.02	0.05	-0.13	-0.25	-0.21	-0.22	-0.20	-0.16
Risky	0.27	0.32		0.22	0.02	0.08	-0.15	-0.24	-0.21	-0.23	-0.20	-0.14
Artificial	0.17	0.20	0.22		0.08	0.13	-0.02	-0.13	-0.07	-0.13	-0.10	-0.08
Quick Fix	0.00	0.02	0.02	0.08		0.05	-0.02	-0.03	0.00	-0.03	-0.04	0.01
Eyesore	0.05	0.05	0.08	0.13	0.05		-0.02	-0.05	-0.03	-0.07	-0.04	-0.02
Understandable	-0.13	-0.13	-0.15	-0.02	-0.02	-0.02		0.21	0.21	0.20	0.17	0.10
Beneficial*	-0.24	-0.25	-0.24	-0.13	-0.03	-0.05	0.21		0.26	0.32	0.30	0.18
Controllable	-0.20	-0.21	-0.21	-0.07	0.00	-0.03	0.21	0.26		0.25	0.25	0.16
Env. Friendly	-0.21	-0.22	-0.23	-0.13	-0.03	-0.07	0.20	0.32	0.25		0.27	0.18
Sustainability	-0.19	-0.20	-0.20	-0.10	-0.04	-0.04	0.17	0.30	0.25	0.27		0.19
Cost effective	-0.16	-0.16	-0.14	-0.08	0.01	-0.02	0.10	0.18	0.16	0.18	0.19	

*Unpredictable and Beneficial were both correlated with other attributes and were therefore removed.

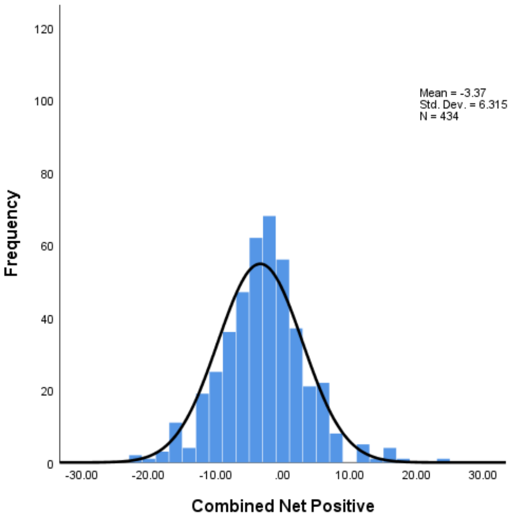
5 Net positive variable statistics

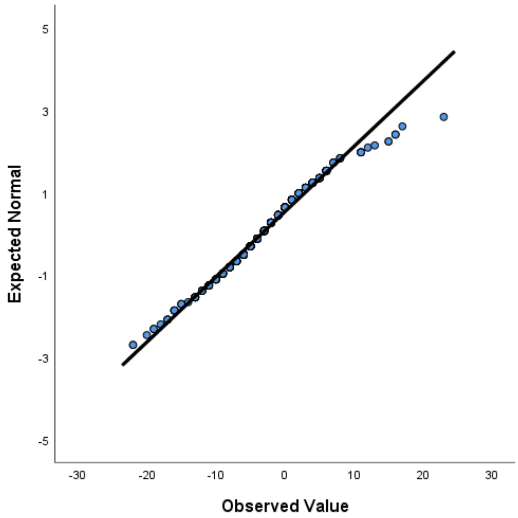
Supplementary Table 4 | Net positive variable statistics

	M	SD	Max	Min	Skewness	Kurtosis
Combined Net Positive						
Type 1	-3.37	6.32	23.00	-22.00	0.23	1.22
Control	-3.28	6.43	20.00	-27.00	0.00	0.48
Type 2	-3.09	6.83	21.00	-29.00	-0.36	1.69
CDR Net Positive						
Type 1	-0.24	4.06	13.00	-12.00	0.07	0.36
Control	-0.30	4.21	13.00	-14.00	0.21	0.23
Type 2	-0.14	4.11	11.00	-15.00	-0.31	0.69
SRM Net Positive						
Type 1	-3.13	3.74	14.00	-13.00	0.46	0.65
Control	-2.98	3.68	9.00	-13.00	0.16	-0.01
Type 2	-2.94	3.89	10.00	-14.00	0.14	0.54

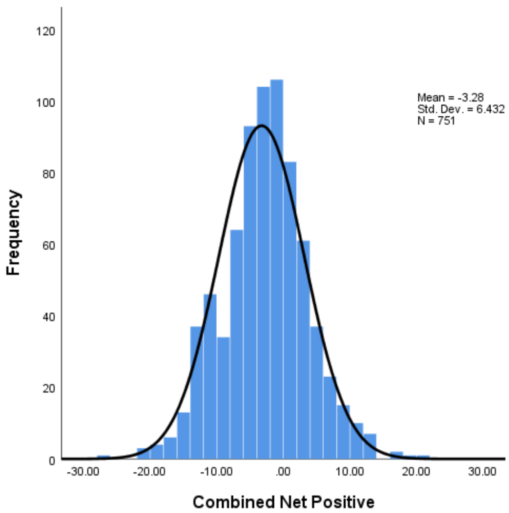
Supplementary Figure 8 | Combined net positive associations – Distribution and Q-Q Plots

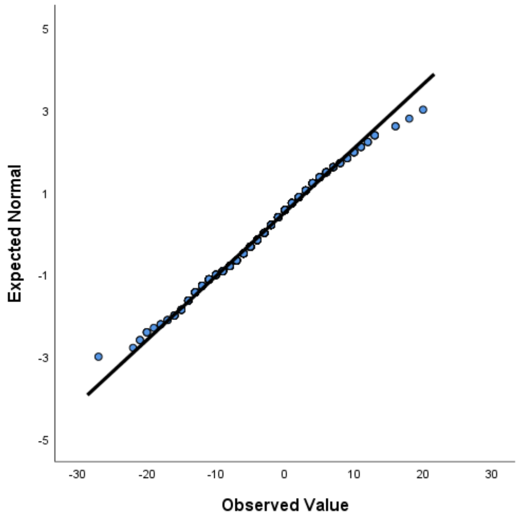
Type 1 treatment



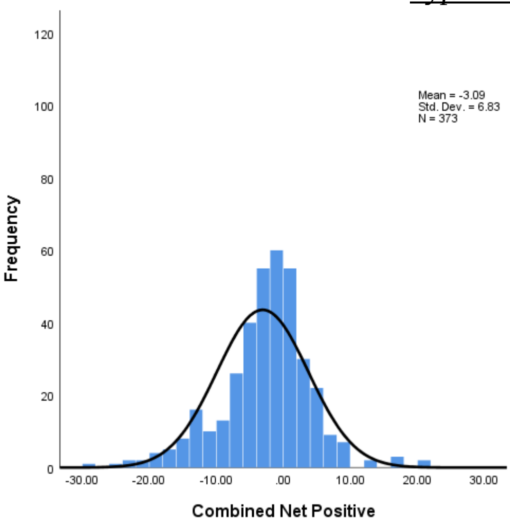


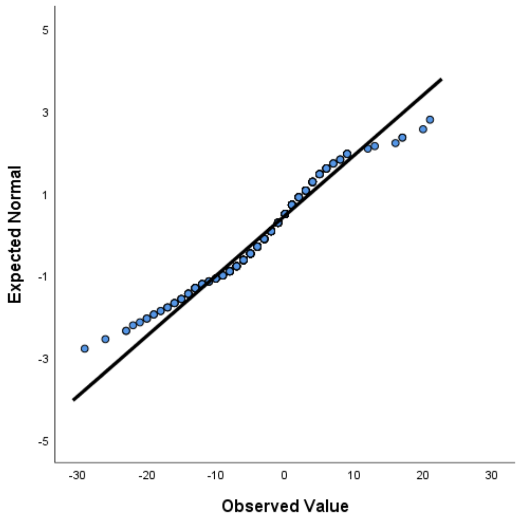
Control treatment





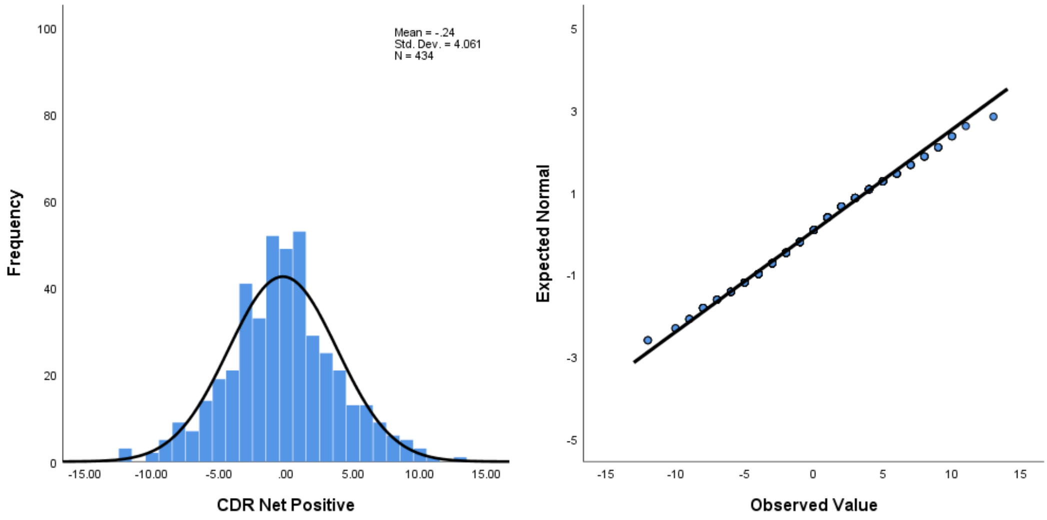
Type 2 treatment



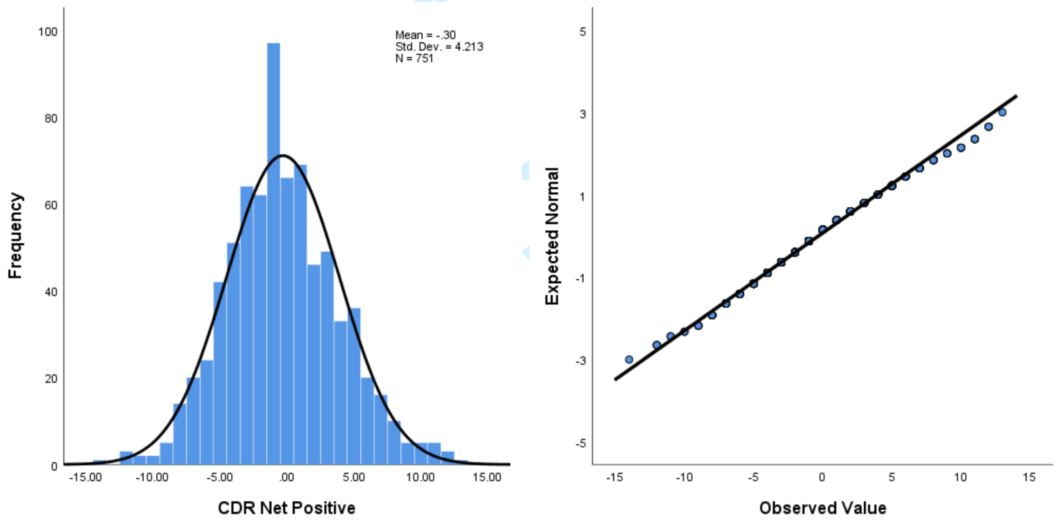


Supplementary Figure 9 | CDR net positive associations – Distribution and Q-Q Plots

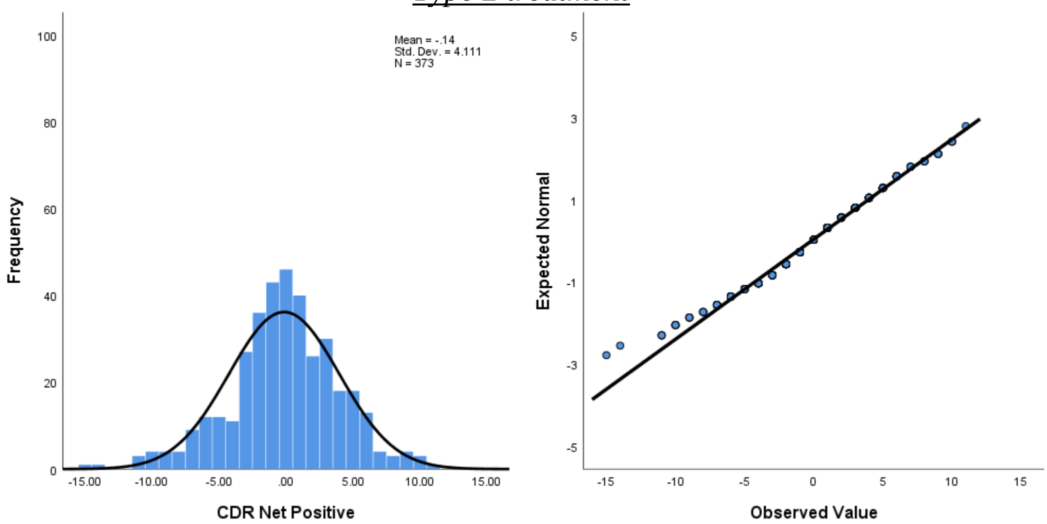
Type 1 treatment



Control treatment

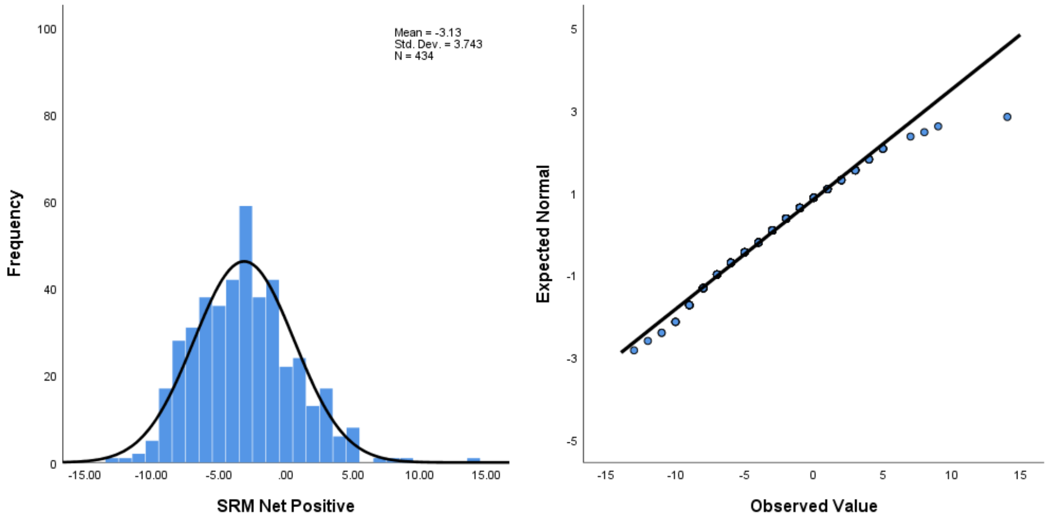


Type 2 treatment

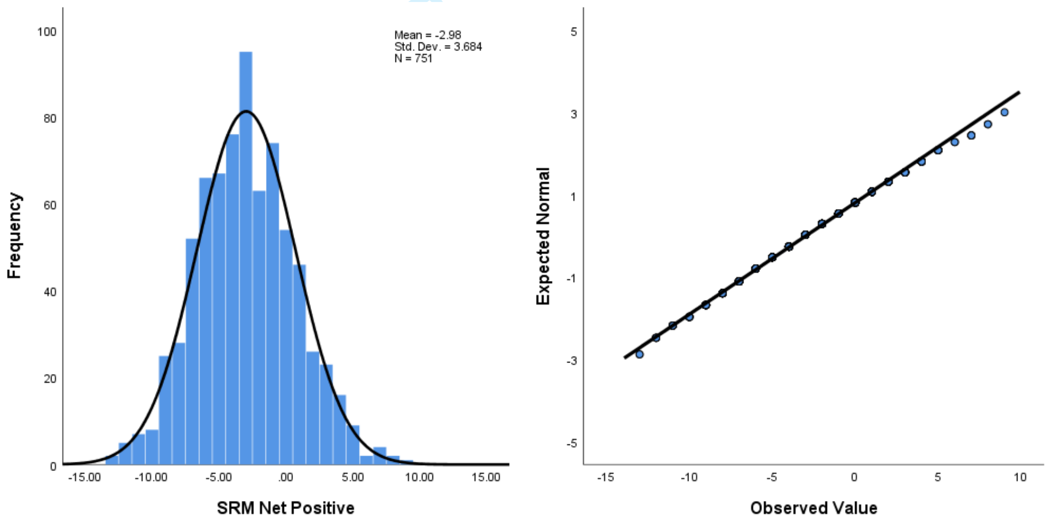


Supplementary Figure 10 | SRM net positive associations – Distribution and Q-Q Plots

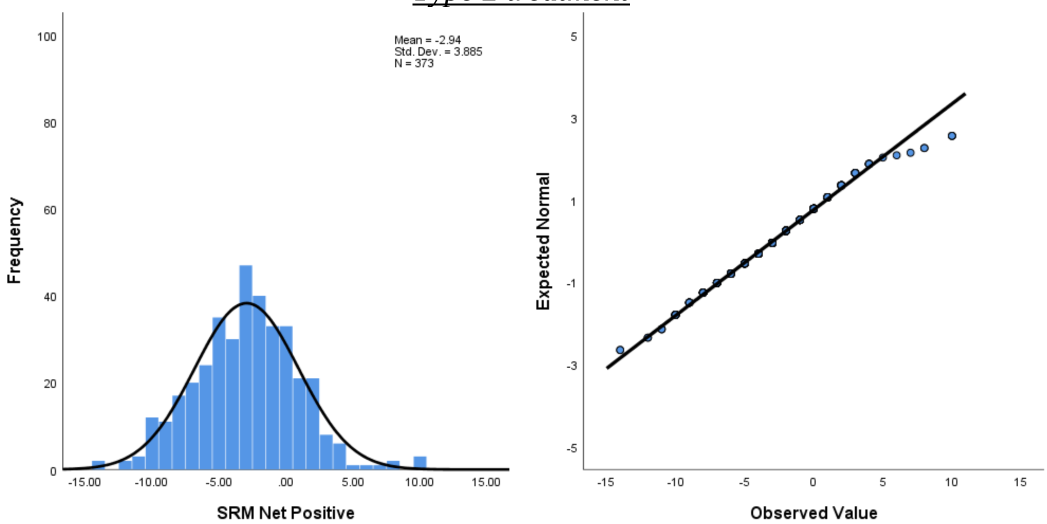
Type 1 treatment



Control treatment



Type 2 treatment



6 Univariate Tests

Supplementary Table 5 | Univariate Tests for Differences on the Net Positive Variable

		Test statistic	Test statistic value	P value	Bonferroni-corrected critical P value
Combined Sample					
Gender	One Way Anova	$\mathbf{F}_{(.05, 1, 1556)}$	0.223	0.637	0.008
Location	One Way Anova	$\mathbf{F}_{(.05, 7, 1550)}$	3.115	0.003	0.008
Education	One Way Anova	$\mathbf{F}_{(.05, 5, 1552)}$	2.691	0.020	0.008
Household Income	One Way Anova	$\mathbf{F}_{(.05, 8, 1549)}$	0.858	0.552	0.008
Political Party	One Way Anova	$\mathbf{F}_{(.05, 6, 1551)}$	7.146*	0.000	0.008
Age	Correlation	**r**	-0.188*	0.000	0.008
Type 1 Treatment					
Gender	One Way Anova	$\mathbf{F}_{(.05, 1, 432)}$	0.494	0.482	0.008
Location	One Way Anova	$\mathbf{F}_{(.05, 7, 426)}$	1.559	0.146	0.008
Education	One Way Anova	$\mathbf{F}_{(.05, 5, 428)}$	1.789	0.114	0.008
Household Income	One Way Anova	$\mathbf{F}_{(.05, 8, 425)}$	0.295	0.967	0.008
Political Party	One Way Anova	$\mathbf{F}_{(.05, 6, 427)}$	2.071	0.056	0.008
Age	Correlation	$\mathbf{r}_{(432)}$	-0.209*	0.000	0.008
Control Treatment					
Gender	One Way Anova	$\mathbf{F}_{(.05, 1, 749)}$	0.017	0.895	0.008
Location	One Way Anova	$\mathbf{F}_{(.05, 7, 743)}$	1.520	0.157	0.008
Education	One Way Anova	$\mathbf{F}_{(.05, 5, 745)}$	2.357	0.039	0.008
Household Income	One Way Anova	$\mathbf{F}_{(.05, 8, 742)}$	1.682	0.099	0.008
Political Party	One Way Anova	$\mathbf{F}_{(.05, 6, 744)}$	4.054*	0.001	0.008
Age	Correlation	$\mathbf{r}_{(749)}$	-0.138*	0.000	0.008
Type 2 Treatment					
Gender	One Way Anova	$\mathbf{F}_{(.05, 1, 371)}$	3.287	0.071	0.008
Location	One Way Anova	$\mathbf{F}_{(.05, 7, 365)}$	2.253	0.030	0.008
Education	One Way Anova	$\mathbf{F}_{(.05, 5, 367)}$	1.275	0.274	0.008
Household Income	One Way Anova	$\mathbf{F}_{(.05, 8, 364)}$	0.748	0.649	0.008
Political Party	One Way Anova	$\mathbf{F}_{(.05, 6, 366)}$	1.896	0.081	0.008
Age	Correlation	$\mathbf{r}_{(371)}$	-0.256	0.000	0.008

*indicates significance at the Bonferroni-corrected critical P value of .008

7 Multivariate Tests

Supplementary Table 6 | Multivariate Tests for Differences on the Net Positive Variable

	F value	P value	Bonferroni- corrected critical P value
Combined Sample (*n* = 1558)			
1 Intercept	1.284	0.257	0.002
2 Gender	1.477	0.225	0.002
3 Location	1.233	0.281	0.002
4 Education	1.056	0.383	0.002
5 Household Income	0.955	0.470	0.002
6 Political Party	1.455	0.191	0.002
7 Age	0.373	0.541	0.002
2×3 Interaction	0.747	0.632	0.002
2×4 Interaction	1.152	0.331	0.002
2×5 Interaction	0.614	0.766	0.002
2×6 Interaction	1.271	0.268	0.002
2×7 Interaction	0.000	0.988	0.002
3×4 Interaction	0.712	0.894	0.002
3×5 Interaction	0.737	0.926	0.002
3×6 Interaction	1.025	0.429	0.002
3×7 Interaction	0.586	0.767	0.002
4×5 Interaction	1.110	0.298	0.002
4×6 Interaction	1.115	0.306	0.002
4×7 Interaction	0.660	0.654	0.002
5×6 Interaction	0.796	0.839	0.002
5×7 Interaction	1.688	0.097	0.002
6×7 Interaction	0.916	0.483	0.002
Control Treatment (*n* = 751)			
1 Intercept	0.067	0.796	0.002
2 Gender	0.459	0.499	0.002
3 Location	0.308	0.950	0.002
4 Education	0.240	0.945	0.002
5 Household Income	0.689	0.701	0.002
6 Political Party	0.908	0.489	0.002
7 Age	0.001	0.969	0.002
2×3 Interaction	0.431	0.883	0.002
2×4 Interaction	0.427	0.830	0.002
2×5 Interaction	0.430	0.903	0.002
2×6 Interaction	0.862	0.507	0.002
2×7 Interaction	0.603	0.438	0.002
3×4 Interaction	0.877	0.664	0.002
3×5 Interaction	0.571	0.994	0.002
3×6 Interaction	0.847	0.717	0.002
3×7 Interaction	0.445	0.873	0.002
4×5 Interaction	1.102	0.317	0.002
4×6 Interaction	0.825	0.700	0.002
4×7 Interaction	0.173	0.972	0.002
5×6 Interaction	0.810	0.787	0.002
5×7 Interaction	0.669	0.719	0.002
6×7 Interaction	1.314	0.257	0.002
Type 1 Treatment (*n* = 434)			
1 Intercept	0.179	0.672	0.002
2 Gender	0.153	0.696	0.002
3 Location	1.098	0.367	0.002
4 Education	1.336	0.252	0.002
5 Household Income	1.341	0.227	0.002
6 Political Party	0.336	0.917	0.002
7 Age	0.974	0.325	0.002
2×3 Interaction	0.648	0.716	0.002
2×4 Interaction	0.563	0.690	0.002
2×5 Interaction	0.762	0.637	0.002
2×6 Interaction	2.389	0.053	0.002

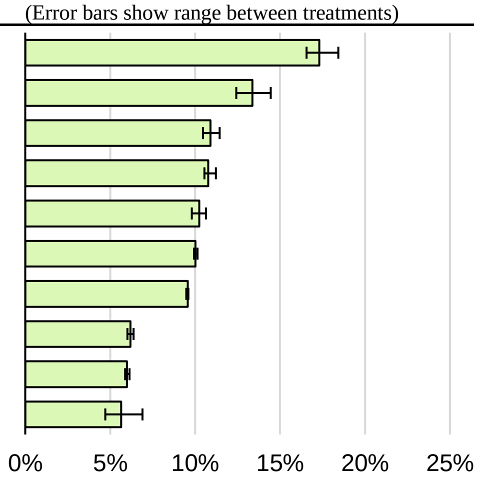
2×7 Interaction	0.164	0.686	0.002
3×4 Interaction	1.080	0.369	0.002
3×5 Interaction	0.837	0.761	0.002
3×6 Interaction	1.417	0.090	0.002
3×7 Interaction	1.152	0.334	0.002
4×5 Interaction	0.980	0.501	0.002
4×6 Interaction	1.316	0.190	0.002
4×7 Interaction	1.063	0.377	0.002
5×6 Interaction	1.175	0.264	0.002
5×7 Interaction	1.476	0.170	0.002
6×7 Interaction	0.382	0.860	0.002
Type 2 Treatment (*n* = 373)			
1 Intercept	0.023	0.881	0.002
2 Gender	0.013	0.910	0.002
3 Location	1.348	0.237	0.002
4 Education	2.223	0.058	0.002
5 Household Income	0.965	0.468	0.002
6 Political Party	0.883	0.510	0.002
7 Age	0.001	0.982	0.002
2×3 Interaction	1.295	0.267	0.002
2×4 Interaction	1.720	0.152	0.002
2×5 Interaction	0.469	0.855	0.002
2×6 Interaction	0.709	0.588	0.002
2×7 Interaction	0.128	0.721	0.002
3×4 Interaction	1.526	0.072	0.002
3×5 Interaction	1.603	0.026	0.002
3×6 Interaction	1.865	0.017	0.002
3×7 Interaction	1.571	0.164	0.002
4×5 Interaction	1.224	0.234	0.002
4×6 Interaction	1.268	0.234	0.002
4×7 Interaction	1.933	0.111	0.002
5×6 Interaction	1.434	0.103	0.002
5×7 Interaction	1.114	0.361	0.002
6×7 Interaction	0.172	0.972	0.002

8 Attribute Popularity (Salience) Split by CDR and SRM

The main manuscript reports the ranked attributes by popularity as an aggregate across the six CDR and SRM technologies. As there are substantial differences in perceptions between CDR and SRM technologies, *Supplementary Tables 7 and 8* report the same data, split by class of technique. The percentage share of associations varies between CDR and SRM technologies but is remarkably consistent across treatments (see error bars, *Supplementary Tables 7 and 8*). In line with previous research (Carlisle et al., 2020; Wright et al., 2014) the negative attributes *unknown effects* and *risky*, rank the highest by popularity (salience) and account for approximately 30% of the total CDR attribute associations and approximately 45% of the total SRM attribute associations.

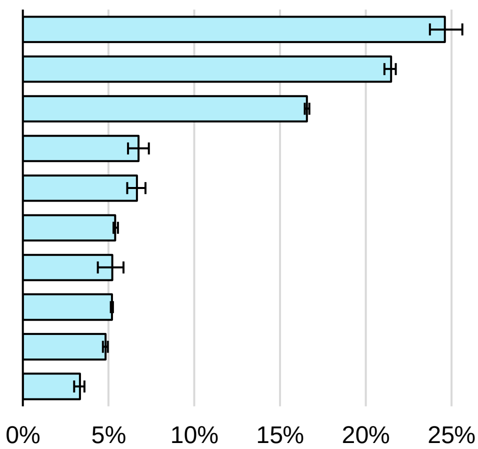
Supplementary Table 7 | Attribute popularity for CDR approaches, as % of associations

Rank	Attribute	Type 1	Control	Type 2	Mean (Error bars show range between treatments)
1	Unknown effects	17	18	17	
2	Risky	12	13	14	
3	Understandable	10	11	11	
4	Environmentally friendly	11	11	11	
5	Controllable	10	10	11	
6	Long-term sustainability	10	10	10	
7	Artificial	9	10	10	
8	Cost effective	6	6	6	
9	Eyesore	6	6	6	
10	Quick-fix	7	5	5	



Supplementary Table 8 | Attribute popularity for SRM approaches, as % of associations

Rank	Attribute	Type 1	Control	Type 2	Mean (Error bars show range between treatments)
1	Unknown effects	24	26	24	
2	Risky	21	22	22	
3	Artificial	17	16	17	
4	Understandable	7	6	7	
5	Quick-fix	7	7	6	
6	Environmentally friendly	6	5	5	
7	Eyesore	5	4	6	
8	Controllable	5	5	5	
9	Long-term sustainability	5	5	5	
10	Cost effective	3	4	3	



9 Supplementary References (see main manuscript for other references)

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