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Negative verbal probabilities undermine communication of climate science

Article

Supplemental Material

Juanchich, M., Teigen, K. H., Shepherd, T. G. ORCID: https://orcid.org/0000-0002-6631-9968 and Sirota, M. (2025) Negative verbal probabilities undermine communication of climate science. Nature Climate Change, 15 (12). pp. 1300-1306. ISSN 1758-6798 doi: 10.1038/s41558-025-02472-1 Available at https://centaur.reading.ac.uk/124738/

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To link to this article DOI: http://dx.doi.org/10.1038/s41558-025-02472-1

Publisher: Nature Publishing Group

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https://doi.org/10.1038/s41558-025-02472-1

Negative verbal probabilities undermine communication of climate science

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Supplementary Information

"Negative verbal probabilities undermine communication of climate science"

Nature Climate Change

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A. Characteristics of participants from Experiments 1-6

Table SI 1

Characteristics of participants from Experiments 1-6

	Experiments					
	1	**2**	**3**	**4**	**5**	**6**
Sample size *N*	301	481	414	497	802	873
***M* age**	40	43	41	47	46	46
SD age	13	14	12	15	16	15
Gender						
Men	50%	50	48	50	47	48
Women	49%	49	51	51	52	51
Non-binary	1%	1	0.2	0.4	0.4	0.1
Prefer not to say	0.3%	0.2	0.2	0.4	0.4	0.2
Education						
< high school	1%	1	1	1	1	2
High school	33%	35	32	34	34	32
Bachelor	46%	43	42	46	43	40
Master’s	16%	15	18	13	16	19
PhD/doctorate	2%	3	5	3	2	3
Other	2%	3	3	3	4	4
Ethnicity						
Black British	2%	3	3	3	4	5
Black other	0%	1	2	1	4	6
Asian British	3%	4	6	5	6	2
Asian other	2%	1	3	2	1	1
White British	83%	82	76	80	76	76
White other	7%	8	8	8	7	9

		Experiments				
Other	3%	3	2	1	2	2
Native English speaker	95%	94	93	95	95	95
English proficiency in non-native speakers (n)	(14)	(29)	(28)	29	40	(41)
Expert	50%	66	57	65	70	56
Advanced	50%	28	39	35	30	34
Intermediate	0%	7	4	0	0	10
Beginner	0%	0	0	0	0	0
Political voting preference						
Conservative party	--	--	--	--	16	17
Green party	--	--	--	--	8	9
Labour	--	--	--	--	39	36
Liberal Democrats	--	--	--	--	11	10
Reform UK	--	--	--	--	16	12
Scottish/Welsh nationalist party	--	--	--	--	3	4
No party	--	--	--	--	6	3

Note: Percentages were rounded up so the total might sometimes exceed 100%.

Climate change related beliefs.

In Experiment 4, a large majority of participants believed that global warming occurring now was likely or very likely (90%) and only a minority believed it was unlikely or very unlikely (5%) – 6% were unsure.

In experiment 5, most of the participants had never heard of the IPCC before taking the survey: 76% reported that they had never heard of the IPCC (23% knew of it). A substantial minority of 16% (n = 126) reported that they had heard information from the IPCC (e.g., in the news), and 8% (n = 60) reported that they had read information directly from the IPCC website/reports.

B. Experiment 1 Supplementary Information

Probability perception

As shown in the distributions of Figure SI 1, the probability interpretation of the four verbal probabilities was similar. We conducted a Bayesian ANOVA in SPSS (version 27, default JZS prior) to compare perceived likelihood across four verbal probability expressions. The analysis yielded a Bayes Factor of $BF_{10} = 0.01$, providing strong relative evidence in favour of the null hypothesis. This suggests that participants interpreted the four verbal probabilities similarly, with the data being approximately 100 times more likely under the model assuming no condition effect than under a model that assumes there is an effect. As shown in Table SI 2, most estimates were consistent with IPCC guidelines for unlikely (0-33%), across verbal probability conditions.

Figure SI 1

Distributions of probability interpretations of the four verbal probabilities used in Experiment 1 (between-subjects random allocation), along with the mean and standard deviations of the distributions (kernel density estimate using a Gaussian kernel smoothing algorithm).

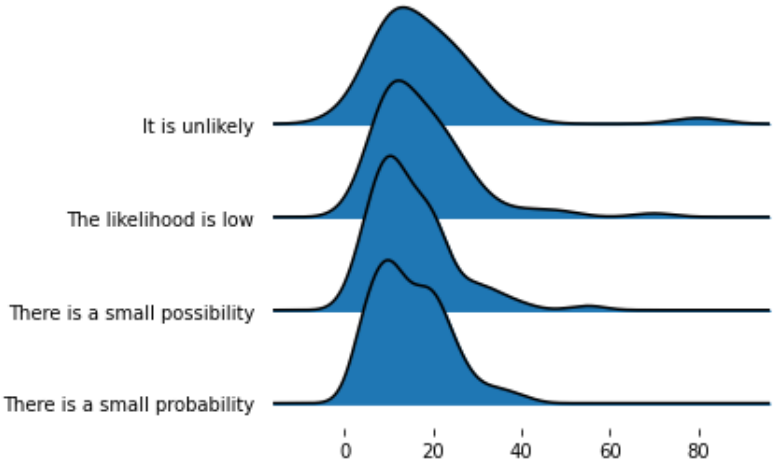


Table SI 2

Mean (SD) probabilistic interpretation of the four verbal probabilities studied in Experiment 1, including the proportion of estimates that fell within the IPCC guidelines low probability guidelines (<33%), along with magnitude of the outcome chosen in the sea level rise sentence completion task

	Probability		Outcome		
	M (*SD*)	% match guidelines	Moderate	Min/max	Beyond min/max
Unlikely	18.68 (13.25)	93% (71/76)	12%[a]	27%[a]	61%[a]
The likelihood is low	17.70 (10.94)	93% (71/76)	21%[a]	39%[a b]	40%[a b]
There is a small probability	15.07 (8.17)	96% (71/74)	28%[a]	51%[b]	21%[b]
There is a small possibility	15.27 (9.26)	95% (71/75)	19%[a]	59%[b]	23%[b]

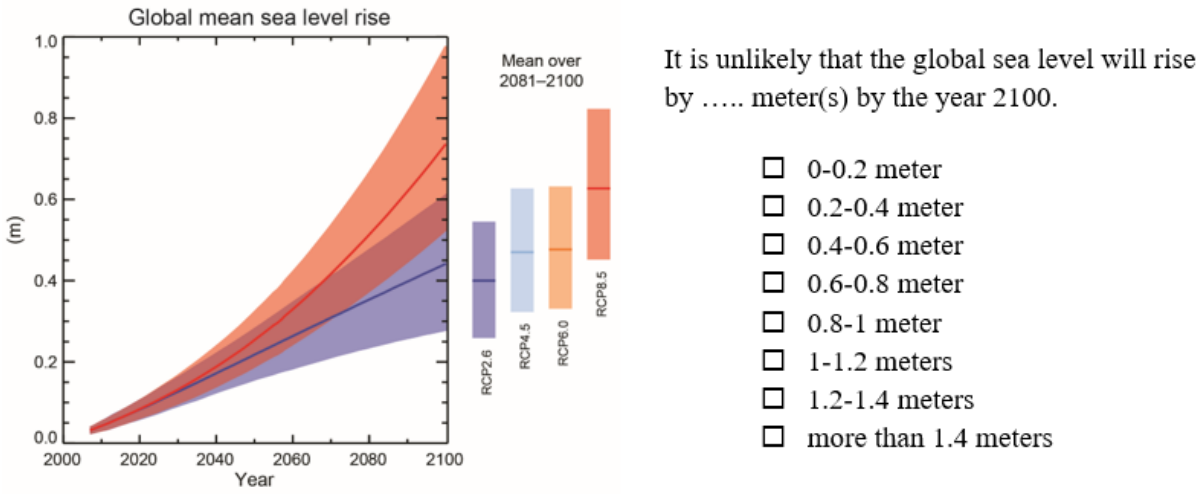
Note: Superscript letters in the Outcome column show condition where the proportion of each category of outcome chosen (shown within the last three columns) did not vary statistically significantly according to pairwise Z test with Bonferroni adjustment.

Distribution of outcomes selection and pairwise comparisons

Table SI 1 shows the frequency of outcomes chosen to complete the sea level rise projection using the IPCC projections shown in Figure SI 2 (outcome values including the CI boundaries at the top and bottom of possible values were coded as minimum/maximum, values within the minimal and maximal values were coded as moderate and values lower than minimal values or higher than maximal values (hence out of range) were coded as extreme. As shown in Table SI 2, participants chose more extreme outcomes when the projection featured a negative verbal probability than when the verbal probability was positive, but the "likelihood is low" did so to a smaller extent than "it is unlikely".

Extended Data Figure 1 (Figure SI 2)

Example of Outcome selection task, showing the IPCC Figure SPM.9 projected sea level rise (IPCC 2013)[1], with an example of probabilistic sentence to be completed based on the plot (the verbal probability varied between-subjects).



Note: The sea level rise plot is Figure SPM.9 from the 2013 IPCC report[1]. It shows "global mean sea level rise from 2006 to 2100 as determined by multi-model simulations. All changes are relative to 1986–2005. Time series of projections and a measure of uncertainty (shading) are shown for scenarios RCP2.6 (blue) and RCP8.5 (red). The mean and associated uncertainties averaged over 2081–2100 are given for all RCP scenarios as coloured vertical bars at the right hand side of each panel. The number of Coupled Model Intercomparison Project Phase 5 (CMIP5) models used to calculate the multi-model mean is indicated" (page 26).

Effect of directionality and effect of task order

In Experiment 1, the experimental conditions were randomised at task level (and not at study level, like in Experiments 2-6, which consistently show an effect of directionality on consensus perception). Hence, some participants saw verbal probabilities that had the same directionality (coded as "matching") or that were different (labelled "mismatched"). For example, participants could read the "unlikely" statement in the outcome selection task and the "likelihood is low" in the consensus assessment task) [matching negative directionality) – or they could see "unlikely" in the outcome selection task and "a small possibility" in the consensus assessment task (mismatching).

The results of Experiments 2-6 evidence that a comparative process is not necessary for directionality to affect consensus perception, but it does not preclude the possibility that comparisons between positive and negative statements would moderate the magnitude of the effect of directionality.

Based on Experiment 1, we have the data to test whether comparative processes might have magnified (or undermined) the effect of directionality on consensus perception and outcome selection. This new analysis showed that the match vs. mismatch did not have a main effect on outcome selection nor on consensus perception, $\chi^2(2) = 0.81$, $p = .668$, $\varphi = .05$ and $\chi^2(2) = 2.16$, $p = .340$, $\varphi = .09$.

Importantly, in a further analysis testing the effect of directionality as a function of the match vs. mismatch condition, we find that the trends remained in the same (and predicted) direction: the two negative verbal probabilities led to more extreme outcomes and fewer consensus perception than the two positive verbal probabilities (see table SI 3).

However, the results also show an interaction tendency. When the directionality of the verbal probability used across tasks "mismatched", the effect of directionality was smaller in the outcome selection task, but it was larger in the consensus task. In the outcome selection task, the effect of directionality was statistically significant when the directionality of the phrases was different across tasks but not when it was the same, $\chi^2(6) = 30.56$, $p < .001$, $\varphi = .45$ and $\chi^2 (6) = 11.35$, $p = .078$, $\varphi = .28$. In contrast, in the consensus perception task, the effect of directionality was statistically significant when the directionality of the phrases was the *same* across tasks, but not when it was different, $\chi^2 (6) = 18.46$, $p = .005$, $\varphi = .36$ and $\chi^2 (6) = 7.91$, $p = .245$, $\varphi = .23$. Hence, it seems that the contrasting effect of showing opposite directionality amplified the association of negative term with extreme outcomes but reduced the perception of negative directionality as a marker of disagreement.

It is important to consider the effect of directionality within each group (match and mismatch) cautiously. The analysis is fully exploratory, and divides the sample by two, and hence reduces the statistical power of the analysis, partly contributing to the drop out of statistical significance. The fact that the results differ across task is also unexpected, as we could have expected the effect to be similar across tasks – not opposite.

Table SI 3

Effect of verbal probability directionality on extreme outcome selection and consensus perception as a function of the matching of the directionality across tasks in Experiment 1 (matching: pos-pos or neg-neg and mismatching: neg-pos or pos-neg).

	Extreme Outcome selection (%)		Perceived consensus (%)	
	n = 145		*n* = 156	
Verbal probability	Matching	Mismatching	Matching	Mismatching
Unlikely (neg)	53%	68%	61%	45%
The likelihood is low (neg)	40%	41%	33%	36%
There is a small probability (pos)	20%	22%	26%	27%
There is a small possibility (pos)	24%	21%	26%	18%

Table note: The percentages shown here rely on a relatively low number of participants, with between 35-41 cases across cells (e.g., in the unlikely matching cell, *n* = 36).

C. Experiment 2 Supplementary Information

Distribution of outcomes chosen

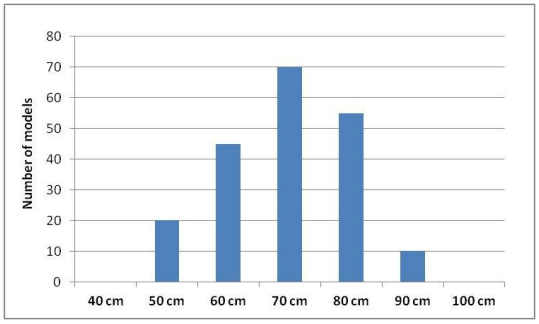
Figure SI 3 shows the Outcome selection task (panel A) and the distribution that participants used to complete the probabilistic statement (panel B).

Figure SI 3

Panel A shows the sea level rise used by participants in the Outcome selection task across the two conditions: "unlikely" and "there is a small possibility". Panel B shows participants' responses (Experiment 2, N = 481).

Panel A.

Outcome selection task: *"It is unlikely [there is a small possibility] that the sea level will rise … cm*



Panel B.

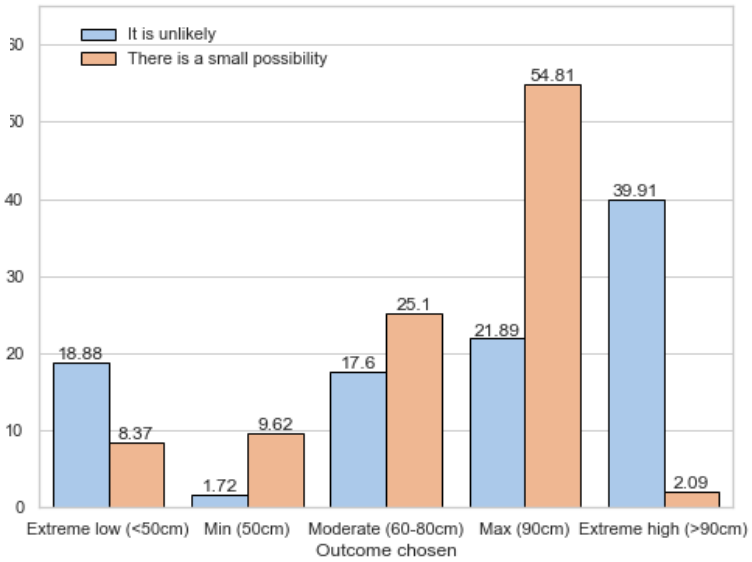
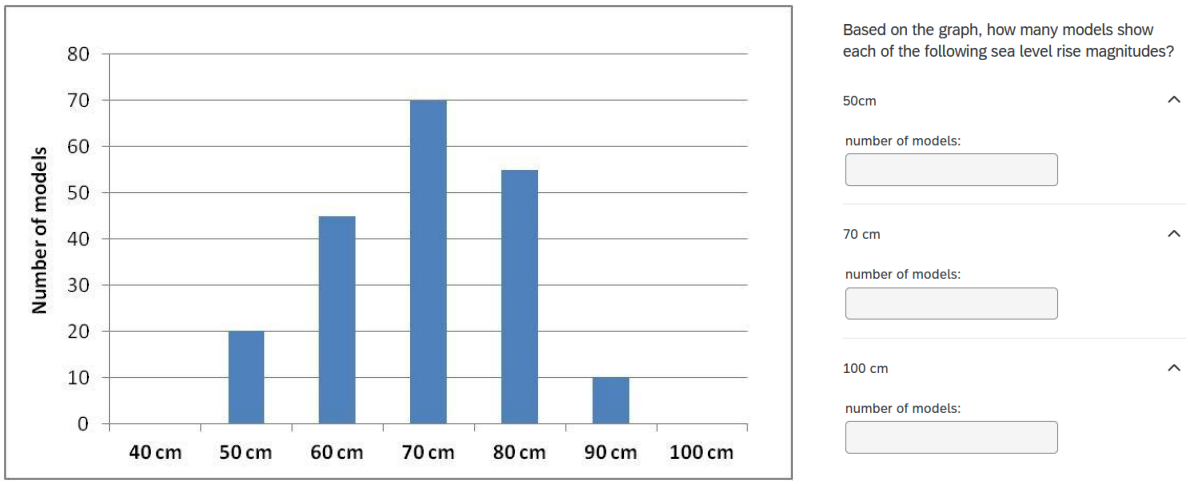


Table SI 3 shows similar information as in the manuscript with the addition of the rate of extreme outcome selection (based on a graph) as a function of participants understanding of the graph.

Outcome chosen and graph literacy

Extended Data Figure 2 (Figure SI 4)
Graphical stimuli used to complete a probability statement (it is unlikely [there is a small possibility] that the sea level will rise … cm), along with the graph comprehension questions.



Most participants correctly answered the three graph comprehension questions shown in SI 4. Participants could accurately identify the number of models showing different sea level rise magnitudes (87%, 89% and 99% of correct answers). When comparing participants who correctly answered all the comprehension questions (86%, n = 418) to those who failed at least one (14%, n = 63), it became apparent that a lower ability to understand the graph could not explain the preference for extreme values. Participants who understood the graph less well chose an extreme value as often as those who answered correctly all the comprehension questions (32% vs. 35%). However, participants with lower graph literacy chose moderate values more often (41% vs. 18%) and minimal/maximal values less often (27% vs. 47%), possibly because of being attracted to the more conspicuous value, $\chi^2(2) = 18.47$, $p < .001$, $\varphi = .20$.

Assessing the effect of directionality on extreme outcome selection as a function of graph comprehension showed that in both lower and high graph comprehension groups, the effect of directionality was in the same direction and consistent with the hypothesis that negative verbal probability would increase extreme outcome selection. However, the effect of directionality was larger in participants with a better graph comprehension (61% vs. 8%), than those who did not fully understand the graph, for whom the effect was not statistically significant (44% vs. 24%),

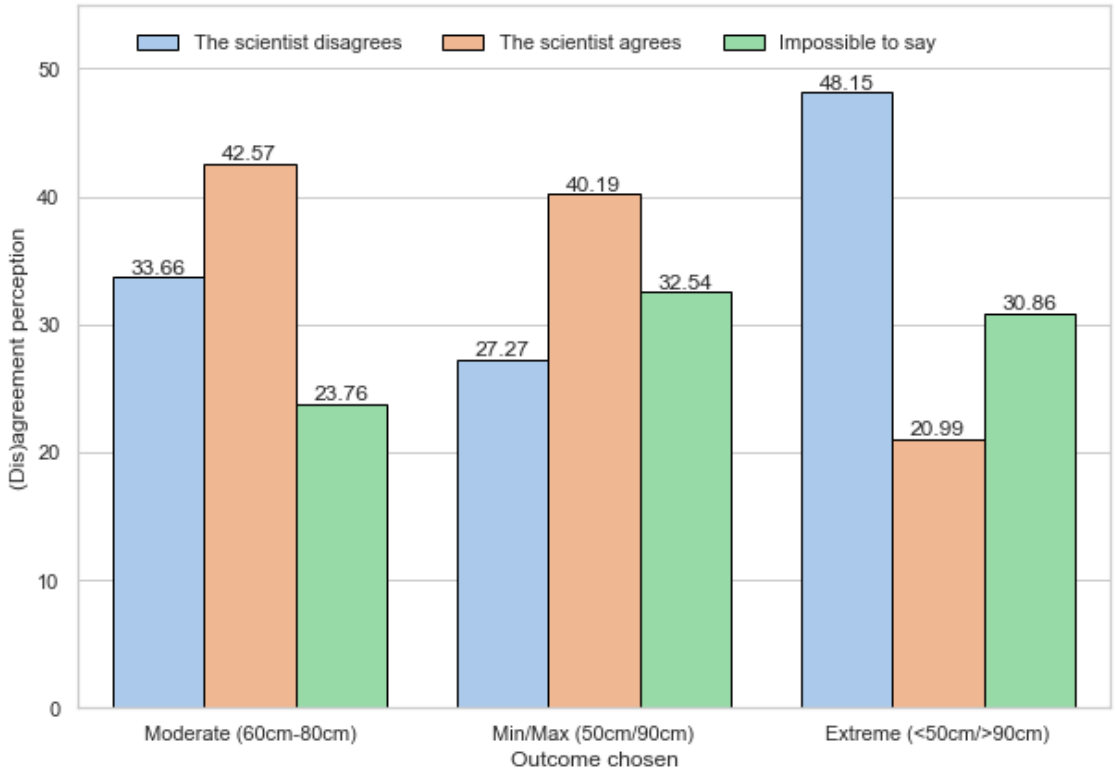
$\chi2(2) = 128.46$, $p < .001$, $\varphi = .56$ and $\chi2(2) = 5.48$, $p = .064$, $\varphi = .30$. Also note the strong imbalance in group sizes, with only 63 participants in the lower comprehension group (25 in the negative condition and 39 in the positive condition).

Relationship between outcome chosen (mix/max, moderate or extreme) and agreement/disagreement perception

Figure SI 5 displays the relationship between participants' responses in the outcome selection task and the perception of agreement/disagreement task. The Figure shows that the tendency to select an extreme outcome (right hand side) and the perception that a person making such a statement expressed a disagreement were related (more disagreement responses on the right).

Figure SI 5

Distribution of agreement/disagreement/can't say perception for "unlikely" and "there is a small possibility" in the Agreement task as a function of the outcome selected in the Outcome selection task (Experiment 2, N = 481).



D. Experiment SI-A

This study aimed to evaluate the effect of directionality on outcome selection and agreement perception and is only reported in Supplementary Information. This section includes the method and the results for that experiment.

Method

Participants

Overall, 298 participants completed the study fully and they all met completion time that we deemed appropriate (≥ 2 min for a study that had a median completion time of 5 min). Participants were between 18 and 82 years old (M = 40.63, SD = 14.08), 49% men, 49% women, 0.4% non-binary and 1% preferred not to say. Education ranged from less than high school (0.3%) to PhD/doctorate (4%). In between, 34% had a high school diploma, 43% had a Bachelor's degree, 17% had a Master's degree, and 2% had other qualifications. Participants were mostly White British (83%), 5% were British of another ethnicity, and the others were non-British. A large majority were native English speakers (93%) and among the 7% who were not (n = 22), 41% estimated their level of proficiency in English as expert, 50% as Advanced and 9% as intermediate (0% beginner).

Design, Materials and Procedure

We compare climate change predictions including two negative probability quantifiers used in the IPC report, "unlikely" and the alternative "the likelihood is low" to two positive ones trialled in past research as conveying similar probabilities "there is a small probability" and "there is a small possibility". We compare these four phrases between-subjects in two tasks focusing on different climate change outcomes.

Outcome selection based on sea level rise data.

Participants completed a probability statement including one of the four verbal probabilities with the outcome of their choice from a list of 8 values ranging from 0-0.2 meter (1) to more than 1.4 meters (8). Values coded as 1, 6, 7 and 8 were coded as "extreme" out of the range, values coded as 2 and 5 were minimal and maximal values respectively and values in between 3-4 were coded

as moderate. The outcome selection task was the same as in Experiment 1 (shown in Figure SI 2).

Consensus perception regarding temperature rise.

Participants imagined that in a TV round table with several climate change scientists, one of them said one of the four probabilistic statements about temperature becoming 3 degrees warmer. Based on that statement, participants assessed whether the scientist agreed or disagreed with the other scientists of the round table on how much the temperature would increase. Participants also had the option to answer "impossible to say".

Results

When asked which sea level rise magnitude was "unlikely", a majority of participants selected an outcome that was not even depicted within the confidence intervals of the climate models shown in the graph: 69% chose a value below or above the actual highest possible sea level rise magnitude (over 1 meter, or below 0.1 meter) – see Table SI 4. This was also frequent, but to a smaller extent with "the likelihood is low", which was associated with such extreme outcome by 44% of the respondents. In contrast, the selection of extreme outcomes dropped to 31% for "a small probability" and 26% for "a small possibility". The verbal probability had an effect on the outcome selected, $\chi^2(21, N = 298) = 59.54$, $p < .001$, *Cramer's V* = .32.

The two negative probability statements describing temperature rise were perceived as indicating a disagreement at least twice more often than the two positive probability statements: 54% believed that "an unlikely temperature rise" indicated a disagreement whereas, just over 41% believed so with "the likelihood is low" – which contrast with the perception of respondents with the two positive probability phrases that were only taken to indicate a form of disagreement by about 20% of the respondents, Pearson $\chi^2(6, N = 298) = 35.62$, $p < .001$, *Cramer's V* = .24.

Table SI 4

Participants interpreted negative probability phrases as a form of disagreement between scientists and associated those phrases with more extreme outcomes.

Statement	% of disagreement perception	% of extreme outcomes
Unlikely	54%	69%
The likelihood is low	41%	44%
There is a small probability	20%	31%
There is a small possibility	20%	26%

E. Experiment SI-B

In experiment 1 and 2 reported in the manuscript and in Experiment SI-A reported in the Supplementary Information, we tested the effect of directionality on consensus perception using two positive and two negative verbal probability phrases. We found that phrases that featured negative verbal probabilities like "unlikely" led to a lower perception of consensus. Here we further explore the nature of directionality and test different ways to elicit a focus on extreme outcome and the perception of disagreement.

Based on past research, it is clear that the nature of the words has an impact on their directionality – for example, "unlikely" is negative and "possible" is positive (Teigen & Brun, 1995), but directionality also depends on the association between the probability words and other syntactic elements of the sentence (e.g., other adjective, negations). For example, "not unlikely" would be positive and "not possible" would be negative. The results of Experiment 1 from the manuscript also suggested that the order of the words (the syntactic structure of the statement) could have an effect on its meaning. For example, if we consider the pair compared in Experiment 1 shown below, a) was positive and b) negative, although they include words that are very similar (probability and likelihood are both positive) and low and small simply seem to suggest the magnitude of those attributes. b) was clearly perceived as negative possibly because "low" is more negative than "small", but also possibly because of the order of the words [2] .

a) "There is a small probability" [small is attributive]
b) "The likelihood is low" [low is predicative]

The position of the adjective, placed before or after the noun it qualifies is called attributive and predicative in linguistic. The attributive position of the adjective also involves the use of an article ("a") and the use of a dummy pronoun subject, possibly emphasising the importance of that quantity, whereas the predicative position separates the noun and the adjective with a verb (to be). The distinction between the position of the adjective is a mere syntactic change but it is recognised it can have consequence in the meaning of the phrase [3].

In the present experiment, we aimed to explore new phrases to see if the attributive or predicative position of the adjective low/small could lead to a similar effect. We selected phrases that had not been studied before but that we assumed to be negative or positive because of the position of the adjective: there is a low *probability* vs. the *probability* is low and there is a small *chance* vs. the *chance* is small. We assumed that the postnominal position of the adjective small and low would give the statement a more negative directionality and hypothesised that those statements would lead to more extreme outcome selection and more disagreement perception. The study was preregistered (AsPredicted #163682). The preregistration, the materials and data are available on the Open Science framework (Experiment SI B): https://osf.io/ch4wf/overview.

Method

Overall, 361 started the study but some did not complete it (10 cases) or completed it too fast (1 case, < 2.5 min completion time for a study that had a median completion time of 6.2 min). The remaining 343 participants were between 20 and 77 years old, 49% men, 50% women, 1% non-binary and 0.3% preferred not to say. Education ranged from less than high school (0.3%) to PhD/doctorate (4%), with in between 27% with a high school diploma, 38% with a Bachelor's degree and 16% with a Master's degree and 1% other. Participants were mostly White British (78%), 6% were British from other ethnicity and the others were non-British. A large majority were native English speakers (94%) and among the 6% who were not (n = 20), 50% estimated their level of proficiency in English as expert, 50% as Advanced (0% intermediate or beginner).

Materials and procedure

The materials were the same as in the SI Experiment 1 and Study 1 reported in the manuscript: Participants completed a sentence completion task based on models of temperature rise and an agreement perception task to assess the effect of word order on extreme outcome selection and agreement perception. The only difference is that we used different pairs of verbal probabilities shown in Table SI 5. In each task, the verbal probability was randomly allocated to be one of the four phrases shown, but the randomisation did not include the option to have equal numbers and one of the four conditions had a lower sample than the others (see Table SI 4).

Results

The order of the adjective and noun influenced the outcome selected, but not always in the expected direction. We examined the distribution our outcomes beyond the range (extreme), maximal within the confidence interval or within the distribution.

As shown in Table SI 5, for the Low + probability pair, the post-nominal presentation of “low”, which we assumed to elicit a negative directionality, led to slightly fewer extreme outcome selection than the prenominal presentation and to slightly more disagreement perception, $\chi2(2) = 6.99$, $p = .030$, $\varphi = .20$ and $\chi2(2) = 0.88$, $p = .645$, $\varphi = .07$.

For the small + chance statements, the post-nominal presentation of ‘small’ led participants to choose more extreme outcome than the prenominal presentation (there is a small chance), $\chi2(2) = 8.03$, $p = .018$, $\varphi = .22$. As expected, the post-nominal presentation of ‘small’ was also associated with more disagreement perception, but the difference was not statistically significant, $\chi2(2) = 3.81$, $p = .149$, $\varphi = .15$.

Table SI 5.

Proportion of selection of extreme outcome and disagreement perception as a function of the position of the adjective low or small in a verbal probability statement (pre vs. postnominal) (Experiment SI-B, N = 343).

Statements	% extreme outcome	Disagreement perception
Low + probability		
A low probability (n = 79)	47%	38%
The probability is low (n = 95)	41%	42%
Small + chance		
A small chance (n = 58)	19%	22%
The chance is small (n = 111)	40%	37%

The subtle manipulation of directionality we used here (the chance is small vs. there is a small chance) did not elicit the same change in perspective, suggesting that directionality is not simply the results of the positioning of an adjective, but an interaction between the nature of the quantifiers (e.g., probability, possibility), and the nature of the modifier (e.g., small, low) together with their syntactic structure (the order in which they are presented).

F. Experiment 4 Supplementary Information

Frequency of unlikely and likely in the IPCC reports

IPCC writers often base their projections on a distribution of potential outcomes (e.g., models showing projected sea level rise, temperature, or precipitation). Writers have therefore the possibility of discussing narrow values from the tails of a distribution (i.e., that have a low probability of occurring), describing those as "unlikely", *or* a larger range of outcomes that together have a high probability and can be described as "likely".

Table SI 6 shows that IPCC authors prefer to report likely outcomes rather than unlikely ones. A search through the 6th IPCC report on the physical science basis (2021) showed that "unlikely" was used only 99 times, whereas "likely" was used 2,593 times (whole word search). A similar pattern can be observed in other IPCC reports. Similarly, in the IPCC summary for policy report [4], 'likely' is used 101 times, but 'unlikely' is used only eight times (including four times to simply be defined). Searches include whole words only, hence the results for "likely" do not include "unlikely". It is interesting to note that these numbers include cases where 'unlikely' and 'likely' are only defined, and not used in a prediction (e.g., unlikely = 0-33%). This was the case 4 times in a footnote explaining their meaning according to the IPCC in the summary report (footnote 4 page 4) and 16 times in the full report (cited 4 times each in 5 places) as well as 8 times in the 2023 Synthesis Report.

Table SI 6

Frequency of occurrence of unlikely in likely in the Physical science basis IPCC report [5] and the 2023 synthesis report [6].

Sources (number of pages)	Unlikely	Likely	Likely / Unlikely ratio
IPCC 2021 Summary for Policy makers (51)	8	101	13
IPCC 2021 full report (2,409)	99	2,593	26
IPCC 2023 Synthesis Report (186)	8	186	13

Note: The Likely/Unlikely ratio indicates how many times more the likely verbal probability was used relative to the unlikely one. In the physical science basis full report, the unlikely and likely terms are used 16 in definition of their standardised meaning. In the synthesis report, unlikely and likely were defined in two footnotes explaining their standardised meaning, capturing 8 occurrences of the terms.

Robustness checks. Effect of directionality (unlikely vs. a small possibility) after controlling for climate change belief

Table SI 7 shows the results of variance analyses testing the effect of the predicted outcome (temperature [likely less than] vs. sea level [likely more than]), the verbal probability

directionality (unlikely vs. likely) and their interaction as predictors on perceived consensus and evidence quality. Model 1 tested only the factors manipulated and model 2 tested the same with climate change belief as a covariate. The results of model 1 are reported showed a main effect of directionality, outcome and their interaction on perception of consensus and evidence (as reported in the manuscript). The interaction effect stems from higher estimates of consensus and scientific evidence for "likely more than" temperature increase, than for "likely less than" sea level rise.

The second model shown in Table SI 7 shows the results based on the same analysis but together with climate change belief as a covariate. The results replicate the main effect of directionality and its interaction with outcome. Climate change beliefs (shown in SI section A) did not have a main effect on judgments of consensus and evidence but interacted with the predicted outcome (more than vs. less than).

Table SI 7

Effect of unlikely vs. likely outcomes and their interaction on perceived consensus and scientific evidence. (Experiment 4, N = 497)

	Consensus			Scientific evidence		
Model 1 *F*(1, 495)	F	*p*	η_p^2	*F*	*p*	η_p^2
Directionality (Unlikely vs. likely)	51.56	<.001	.09	27.33	<.001	.05
Outcome (temperature [likely less than] vs. sea level [likely more than])#	43.72	<.001	.08	18.69	<.001	.04
Outcome x Directionality	28.82	<.001	.06	21.69	<.001	.04
Model 2 (with covariate) *F*(1, 494)	F	*p*	η_p^2	*F*	*p*	η_p^2
Directionality (Unlikely vs. likely)	51.47	<.001	.06	28.63	<.001	.06
Outcome (temperature [likely less than] vs. sea level [likely more than])	0.47	.495	<.01	2.21	.138	<.01

Climate change	0.02	.896	<.01	13.96	<.001	.03
Outcome x Directionality	29.28	<.001	.06	22.00	<.001	.04
Outcome x Climate change belief	3.79	.052	.01	5.44	.020	.01

Note: within-subject main effect of Outcome and interaction effect of Outcome x Directionality. Between-subject effects for directionality and climate change belief (Model 2 only). The interval outcome differed across climate context: Temperature: likely less than 2°C vs. unlikely more than 2°C and Sea level: likely less than 0.5 meter vs. unlikely more than 0.5 meter

Exploratory analysis of the correlation between climate change belief, consensus perception and quality of the scientific evidence basis of the climate change projections

To build on the interaction effect between climate belief and the climate outcome projected, we conducted an exploratory correlation analysis. The results showed that climate change belief was positively correlated with perceived consensus and scientific evidence for “more than” likely outcomes– while the correlations were smaller or null for the “likely less than” projections and for unlikely outcomes (see in SI Table 8). We speculate that participants’ judgments were less correlated with climate change beliefs for the likely “less than” outcome (temperature context) than with the likely “more than” outcome (precipitation context), because of a lack of credibility of projections focusing on the lower end of possible temperature rise, while the unlikely projections might have simply been perceived as lacking consensus and scientific evidence basis whatever people’s beliefs.

Table SI 8

Correlations (Pearson) between participants' climate change belief and their consensus and scientific evidence base perception for unlikely and likely projections of temperature and sea level rise in Experiment 4.

Outcome	Correlation coefficient with climate change belief	
DV		
Temp [likely less than]	Unlikely prediction	Likely prediction
Consensus	-.08^{ns}	-.02
Evidence	.01	.16*
Sea level [likely more than]		
Consensus	-.09 ^{ns}	.20**
Evidence	.04 ^{ns}	.37***

Note: *: $p < .05$, **: $p < .01$, ***: $p < .001$

G. Experiment 5 Supplementary Information

Material development

To select the low probability values used in the projections in Experiment 5, we first selected the 90% confidence interval of the most likely temperature rise based on the intermediate Greenhouse Gas emissions (GHG) scenario from the IPCC policy report (Figure SPM8): 2.7°C, 90% CI[2-4.5], 50% CI [2.1C to 3.5C] (with a Z-score of 1.65). The projections imply a 75% CI of around [2.4 to 3.0] (with a Z-score of 0.68). Hence, there is a 75% probability of the warming not reaching 3°C, and less than a 33% probability of it reaching *3*°C.

Pairwise comparisons

Figure SI 6 shows the mean consensus perception, rate of focus on the event (%) and concerns about climate based on the four projection conditions and Table SI 9 shows pairwise comparison within these four conditions. Specifically, the "small probability" projection led to a higher level of perceived consensus than the "unlikely" projection and the "likely…not" one, *MDiff* (with Bonferroni adjustments) = 17.32, $p < .001$, *Cohen's d* = .61, *MDiff* = 19.08, $p < .001$, *Cohen's d* =.67. Furthermore, the low numerical probability projection, also led to higher perceived consensus than the unlikely and the likely projections, *MDiff* = 19.70, $p < .001$, *Cohen's d* =.70 and *MDiff* = 21.45, $p < .001$, *Cohen's d* =.76.

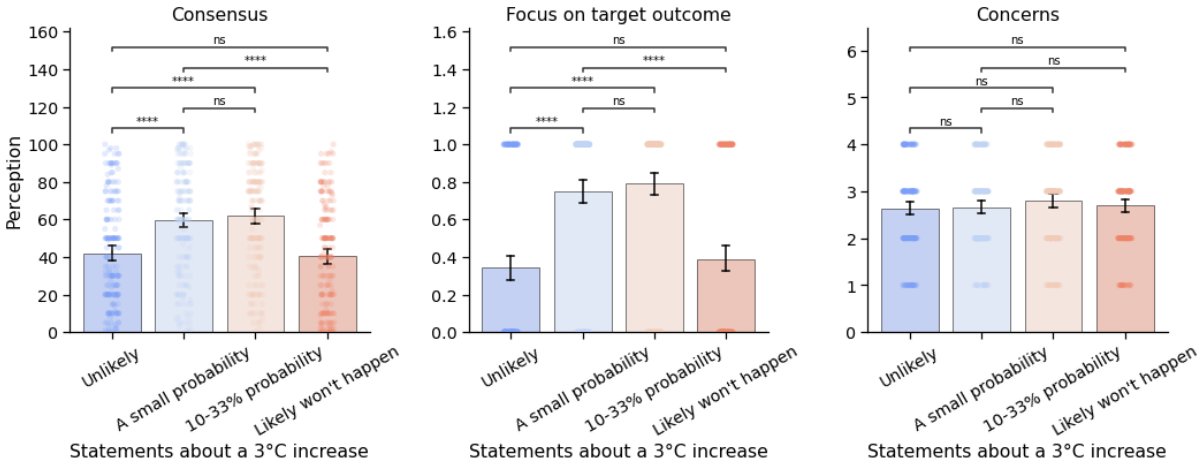
Table SI 9

Pairwise comparisons across the four conditions for consensus and event focus (with Bonferroni adjustment). Pairwise comparisons are not report for climate change concerns as the statement manipulation did not have a statistically significant main effect on that variable (d: Cohen's d).

	MDiff Consensus	*Z test Event focus*
Unlikely vs. A small probability	17.32, $p < .001$, $d = .61$	$p < .05$
Unlikely vs. Likely … not	1.75, $p = .535$, $d = .06$	*ns*
Unlikely vs. 10-30%	19.70, $p < .001$, $d = .70$	$p < .05$
A small proba vs. Likely ... not	19.08, $p < .001$, $d = .67$	$p < .05$
A small proba vs. 10-30%	*2.37*, $p > 0.99$, $d = .08$	*ns*
10-30% vs. Likely ... not	21.45, $p < .001$, $d = .76$	$p < .05$

Figure SI 6

Mean (and 95% CI) consensus, focus on target outcome (%) and concerns as a function of the probability used in the climate projection (Experiment 5).



Robustness of the effect of the projection wording on consensus perception

The effect of the statement condition was robust to the introduction of covariates in the analyses. The effect was similar when we included awareness of the IPCC[1] as a predictor together with political conservatism tendencies and education levels, $F(3, 773) = 28.11$, $p < .001$, $\eta^2_p = .10$. Knowing the IPCC was associated with an increase in perceived consensus, $F(1, 773) = 12.29$, $p < .001$, $\eta^2 = .02$, whereas being more educated and politically conservative was not, $F(1, 773) = 0.57$, $p = .450$, $\eta^2 = .001$, $F(1, 773) = 0.02$, $p = .899$, $\eta^2 < .001$. In a separate analysis, we tested the effect of format and familiarity with the IPCC as factors together with their interactions to see if IPCC familiarity moderated the effect of the statement condition. The results showed that this was not the case ($p > .05$ interaction effect) and simply replicated the main effects of directionality and IPCC familiarity (Table SI 10).

[1] This was coded as a 0-1 variable where 0: Participants had never heard of the IPCC (76%), and 1 had at least heard of it (24%).

We further tested the role of IPCC familiarity by entering it as an independent variable in an analysis of variance together with the projection wording manipulation to see if IPCC familiarity moderated the effect of the prediction. We tested two models, one with the four levels of the prediction manipulation (model 1) and one with only the positive vs. negative low verbal probability (model 2). As shown in Table SI 8, the results replicated the main effects of prediction and IPCC awareness and did not reveal an interaction effect.

Table SI 10

Effect of the projection condition and participants' IPCC awareness on perceived scientific consensus shows a positive main effect and no interaction.

Directionality	F	Sig.	η^2_p
Prediction (4 levels)	27.769	<.001	.095
IPCC familiarity (0/1)	10.06	.002	.013
Prediction x IPCC familiarity	1.80	.145	.007
Model 2 (comparing positive and negative verbal probabilities)			
Directionality (unlikely vs. small probability)	23.92	<.001	.06
IPCC familiarity (0/1)	5.15	.024	.01
Directionality x IPCC familiarity	0.04	.840	<.001

In model 1, the 4 levels of the prediction were: low negative verbal probability, low positive verbal probability, low numerical probability and high positive verbal probability for a complementary outcome. IPCC familiarity: 0: Have never heard of the IPCC; 1: have at least heard of the IPCC.

H. Experiment 6 Supplementary Information

Material development

In Experiment 6, our statements about future temperatures and precipitation focused on the UK, so we used the UKCP18 report to select appropriate values (the Met-Office-produced national climate projections)[1]. We used the values shown in Table 2.1. of the report. We selected values from RCP 2.6 as low emissions (based on assumptions of large changes in GHG emissions) and SRES A1B as high emission scenario, which better reflects current trends. In the study, we present the values as being for 2100 relative to 1981-2000, although technically this is not fully correct since the values are for 2080-2099 minus 1981-2000. As shown in Table SI 11, the unlikely value for the low scenario is comparable to the best estimate for the high scenario.

Table SI 11

Best and unlikely outcome values used in Experiment 6 of the manuscript based on high vs. low emission trends, along with best estimates based on those models.

Emissions scenario	Temperature estimates		Winter precipitation estimates	
	best	Unlikely	best	Unlikely
High (SRES A1B)	+2.7°C	+4.1°C	+13%	+32%
Low (RCP 2.6)	+1.4°C	+2.3°C	+6%	+18%

Note: Unlikely values were estimated to be on the 90th percentile of projections.

Baseline perception and manipulation check

Participants reported moderate expertise with answers slightly below the scale mid-point *M* = 3.56, *SD* = 2.01 (ranging from 0: *Not at all informed* to 10: *Very well informed*) and high trust in climate scientists with an average of 3.56, *SD* = 1.00 (ranging from 1: *A little*, to 5: *Very strongly*).

The baseline responses about temperature and precipitation changes show that participants were more familiar with temperature changes than with winter precipitation changes (see Table SI 10). They reported temperature changes being more often covered in the news, and they perceived that there was a greater scientific consensus about temperature change than about precipitation

winter changes, t(872) = 15.49, $p < .001$, *Cohen's d* = 0.52 and t(729) = 4.38, $p < .001$, *Cohen's d* = 0.16. When asked how temperature and precipitation would change, participants reported fewer «I don't know» about temperature than about winter precipitation changes. When they gave estimates, the estimates for temperature changes were also more often correct than the estimates of precipitation (see Table SI 10). The estimates for how much temperatures might change were more correct, with most estimates falling within the projections based on the low or the high GHG scenario, whereas less than half fell within that range for the precipitation changes and a quarter were below and a quarter above those estimates, reflecting lower accuracy and greater uncertainty (see distribution in Figure SI 7).

Figure SI 7

Distribution of expected most likely temperature and winter precipitation change relative to low likelihood projected values studied. The effect of directionality occurred when the projected values presented as "unlikely" clashed with participants expectations (i.e., in the low GHG temperature change condition).

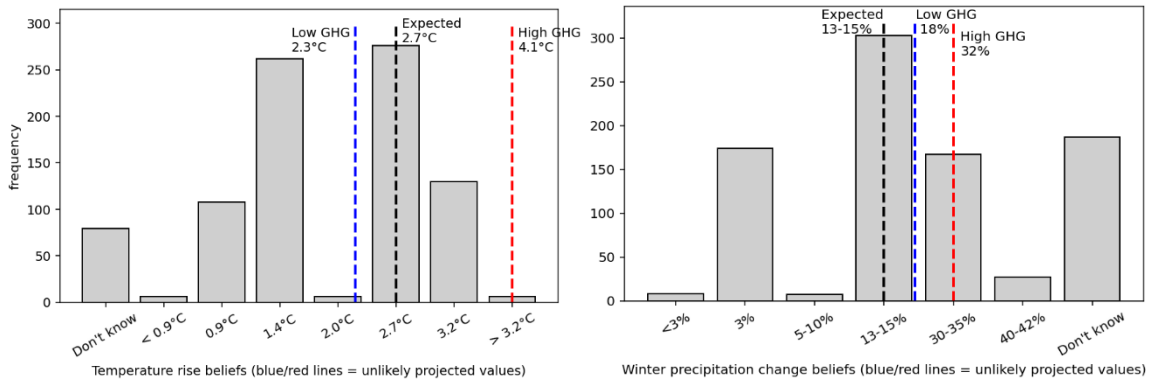


Figure note: Best estimates given by participants before evaluating the low probability outcome based on either low or high GHG emission – shown in blue and red dotted lines respectively. It is unlikely (there is a small probability) that temperature rise will exceed 4.1°C [2.3°C] in the UK. It is unlikely (there is a small probability) that winter precipitation will increase by 32% [18%] in the UK.

We tested the effect of directionality, GHG scenario (between-subjects factors) and outcome (within-subject) conducted an analysis of variance include the outcome as a (within-subject) factor (reported in Table SI 12). The analysis shows a main effect of directionality on concerns

only – and a more complex pattern for perceived consensus and scientific evidence. For those, the analysis shows a triple interaction effect: directionality x GHG emission scenario x outcome. For clarity, in the manuscript we report the effect of directionality and GHG scenario tested separately for each outcome.

Table SI 12

Effect of directionality and scenario for the temperature rise and winter precipitation rise scenario (within-subject) factor.

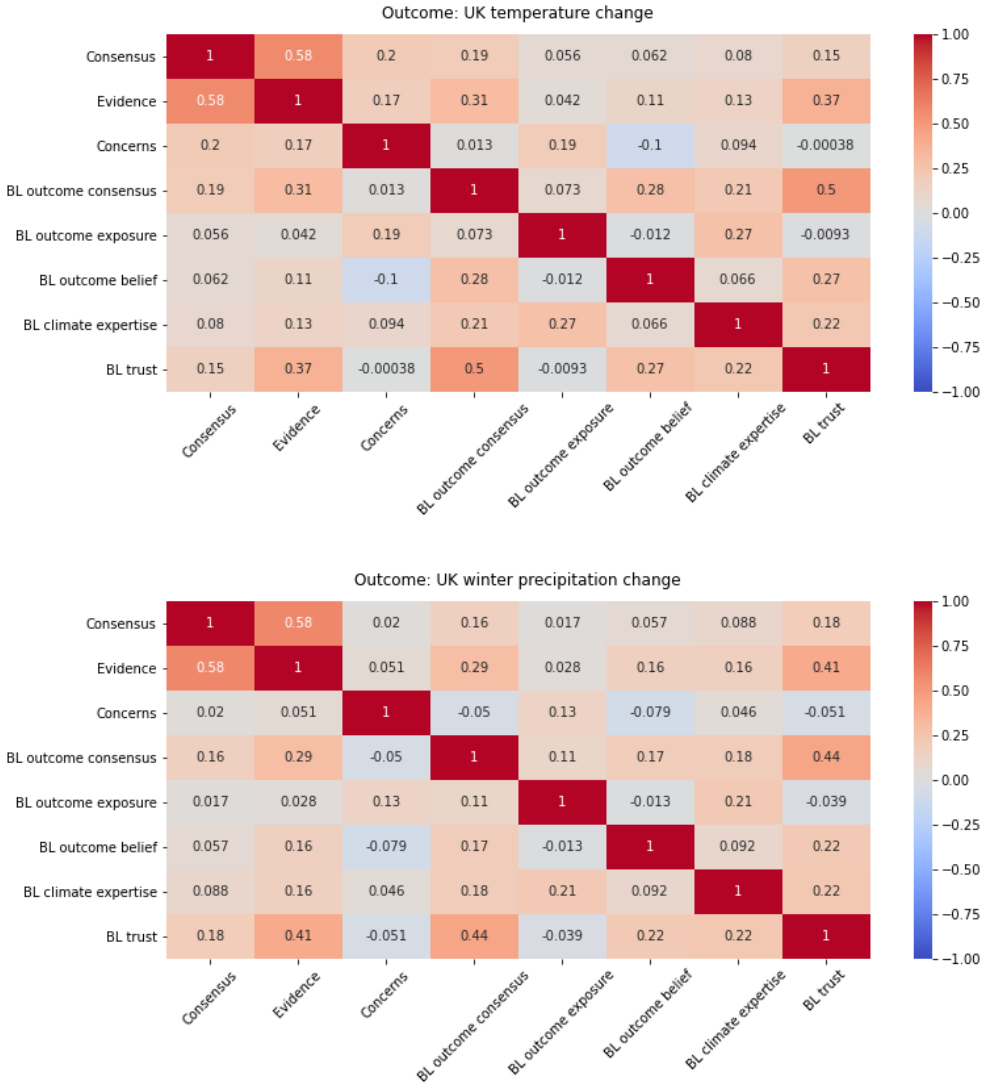
	Consensus			Scientific evidence			Concerns		
	$F(1, 869)$	p	η_p^2	$F(1, 869)$	p	η_p^2	$F(1, 869)$	p	η_p^2
Directionality	1.17	.281	<.01	6.80	.009	.011	69.83	<.001	.07
Outcome	6.29	.012	.01	17.62	<.001	.02	0.80	.373	<.01
Emission	1.07	.301	<.01	0.80	.373	<.01	19.24	<.001	.02
Directionality x Outcome	9.96	.002	.01	5.42	.020	.01	1.32	.250	<.01
Directionality x Emission	18.25	<.001	.02	3.59	.058	<.01	0.05	.823	<.01
Outcome x Emission	0.03	870	<.01	0.01	.914	<.01	1.80	.181	<.01
Directionality x Outcome x Emission	5.81	.016	.01	4.61	.032	.01	1.34	.248	<.01

Table Note: we report the within-subject effects for Outcome, Directionality x Outcome, Outcome x Emission, Directionality x Outcome x Emission and between-subjects effects for the other effects. Directionality: Unlikely vs. a small probability; Outcome: Temperature increase vs. winter precipitation increase; Emission: GHG emission scenario: high/current vs. Low.

Figure SI 8 shows correlation between participants baseline responses and their perceptions of the temperature and precipitation projections.

Figure SI 8

Correlation between baseline measures (BL) and perceptions based on the low probability projections for UK temperature and UK winter precipitation.



Importantly, the events participants felt most likely were the same as the ones presented as having a low likelihood in the low GHG projections for temperature change – the condition in which the effect of directionality of the projection was the largest. In contrast, the estimates fell below the magnitude depicted in the projections for the other conditions (e.g., medium GHG emissions) – conditions for which the effect of directionality was smaller.

Table SI 13

Participants baseline perception about temperature change and winter precipitation change before being shown a low likelihood projection of temperature change of +2.3°C /4.1°C and +18%/32% (based on low/medium GHG emissions).

Baseline perceptions	Temperatures change	Winter precipitation change
Frequency in the news	3.61 (1.2)	3.00 (1.21)
Scientific consensus	3.15 (0.79)	3.06 (0.75)
Expected magnitude:		
Modal choice (%)	+2.7°C (32%)	+13% (35%)
% correct*	69%	45%
% don't know	9% [*n* = 75]	21% [*n* = 185]

References

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