

**Supplemental Material for**  
**Message Quality and Audience Characteristics Shape Evaluation and Impact of Real-**  
**World Social Media Climate Communication**

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## **Section A. Taxonomy for Pro-Climate Communication**

As no taxonomy of climate science and climate action communication was available, we created a novel taxonomy for pro-climate communication that mirrored existing taxonomies for anti-climate communication. Our taxonomy is based on the ‘super claims’ of climate change contrarianism by Coan et al. (2021) and the typology of climate delay by Lamb et al. (2020). It distinguishes between 5 climate science core arguments and four categories for climate action arguments with several subcategories each. The taxonomies for climate science and climate action arguments are detailed in Table S1 and Table S2 respectively, alongside the corresponding contrarian arguments from the analogous anti-climate communication taxonomies. An exemplary message for every category from the *ClimateChirp* database is given.

**Table S1:** Taxonomy of Pro-Climate Messages for Climate-science Related Arguments

<b>Misinformation Superclaims from Coan et al.</b>	<b>Categories for Climate Science Arguments</b>	<b>Example Statement from the <i>ClimateChirp</i> database</b>
Global warming is not happening	Global warming / climate change is happening	Its official. The last five years were the warmest ever recorded.
Human greenhouse gases are not causing climate change	Human greenhouse gas emissions are causing climate change	Humans have increased the CO <sub>2</sub> concentration by 50% from 280ppm to 420ppm. We are now responsible for 33% of the atmospheres CO <sub>2</sub>
Climate impacts/global warming is beneficial/not bad	Impacts and consequences of climate change are severe and negative	Let us remember that the current storms, wildfires, and heat are merely precursors to sea-level rise, loss of the Arctic, biodiversity losses, and water stress that no human society has ever experienced.
Climate solutions won't work	Climate science can identify the most promising climate solutions and climate mitigation is possible	Bioenergy can be used to help decarbonise sectors where electrification is challenging like aviation and shipping See IRENAs International Renewable Energy Agency Global Energy Transformation report to learn how renewables can enable meeting the Paris Agreement
Climate movement/science is unreliable	Climate science (/ movement) is reliable	11,000+ scientists agree — the world will endure untold human suffering if humans don't dramatically reduce GHG emissions. We must take on the greed of the fossil fuel industry and its cronies by declaring a climate emergency.

**Table S2:** Taxonomy of Arguments supporting Climate Action (with corresponding argument opposing climate action from Lamb et al. 2020). Exemplary statements are provided for every main category.

<p><b>1 Responsibility</b></p> <p><i>It is crucial to take individual climate action namely to show the example. But it cannot be the whole solution to the climate crisis, we need companies and governments to act as boldly and quickly as possible.</i></p>	<p><b>Individual responsibility</b> Individuals hold responsibility, especially rich people/ Western societies that have historically contributed most to climate change.</p> <hr/> <p><b>Political responsibility</b> Policy measures and system level solutions are needed to foster large scale climate action.</p> <hr/> <p><b>Global responsibility</b> Climate change is a global crisis that needs to be tackled globally. Global cooperation in mitigation efforts should be enforced.</p>	<p><b>Whataboutism</b> Our carbon footprint is trivial compared to [...]. Therefore, it makes no sense for us to take action, at least until [...] does so.</p> <hr/> <p><b>Individualism</b> Individuals and consumers are ultimately responsible for taking actions to address climate change</p> <hr/> <p><b>The free rider excuse</b> Reducing emissions is going to weaken us. Others have no real intention of reducing theirs and will take advantage of that.</p>
<p><b>2 Disruptive change:</b> Push transformative solutions</p> <p><i>The ozone hole is healing because we stopped emitting freon. Now we need to stop the use of fossil fuels.</i></p>	<p><b>Technological realism</b> Climate solutions should not rest on potential technologies that are yet to be developed. Waiting for technological solutions cannot replace climate action.</p> <hr/> <p><b>Words followed by action</b> Climate agreements and pledges need to be implemented; real change rather than symbolic climate tokenism is needed.</p> <hr/> <p><b>Transition away from fossil fuels</b> To reduce greenhouse gas emissions, a transitioning away from using fossil fuels is needed.</p> <hr/> <p><b>Appropriate Incentives &amp; Consequences</b> Fostering appropriate incentives, economic or ‘hard’ policies, instead of waiting for voluntary changes.</p>	<p><b>1 Redirecting Responsibility</b> (Someone else should act first)</p> <hr/> <p><b>2 Disruptive Change is not necessary:</b> push non-transformative solutions</p> <hr/> <p><b>Technological optimism</b> We should focus our efforts on current and future technologies, which will unlock great possibilities for addressing climate change.</p> <hr/> <p><b>All talk, little action</b> We are world leaders in addressing climate change. We have approved an ambitious target and have declared a climate emergency.</p> <hr/> <p><b>Fossil fuel solutionism</b> Fossil fuels are part of the solution. Our fuels are becoming more efficient and are the bridge towards a low-carbon future.</p> <hr/> <p><b>No sticks, just carrots</b> Society will only respond to supportive and voluntary policies, restrictive measures will fail and should be abandoned.</p>

<p>3</p> <p><b>Emphasize the upsides of Climate Change mitigation</b></p> <p><i>Wind and solar are far better for wildlife than coal-fueled warming, air pollution, and water pollution.</i></p>	<p><b>Policy realism</b></p> <p>Climate policies may not be perfect, but their benefits outweigh the costs.</p> <hr/> <p><b>Well-being co-benefits</b></p> <p>Climate mitigation can have multiple co-benefits, e.g. improve public health or reduce social inequalities.</p> <hr/> <p><b>Climate justice</b></p> <p>The Global South, poor and marginalized people are particularly vulnerable to climate change despite having contributed to climate change least. Can apply to ecosystems more broadly as deserving of protection.</p>	<p><b>Policy perfectionism</b></p> <p>We should seek only perfectly-crafted solutions that are supported by all affected parties; otherwise, we will waste limited opportunities for adoption.</p> <hr/> <p><b>Appeal to well-being</b></p> <p>Fossil fuels are required for development. Abandoning them will condemn the global poor to hardship and their right to modern livelihoods.</p> <hr/> <p><b>Appeal to social justice</b></p> <p>Climate actions will generate large costs. Vulnerable members of our society will be burdened; hard-working people cannot enjoy their holidays.</p>
<p>4</p> <p><b>No surrender, change is still possible</b></p> <p><i>Hands up who expected five years ago that globally wind and solar combined are now generating more energy than nuclear</i></p>	<p><b>Hope and solutions</b></p> <p>Climate action is not futile and the time to act is now.</p> <hr/> <p><b>Change is possible (in democratic systems)</b></p> <p>Large scale climate action is possible and a majority of people supports it. Features success stories of climate action.</p>	<p><b>3</b></p> <p><b>Change will be disruptive:</b></p> <p>Emphasize the Downsides</p> <hr/> <p><b>4</b></p> <p><b>It's not possible to mitigate climate change: surrender</b></p> <hr/> <p><b>Doomism</b></p> <p>Any mitigation actions we take are too little, too late. Catastrophic climate change is already locked-in. We should adapt, or accept our fate in the hands of God or nature.</p> <hr/> <p><b>Change is impossible</b></p> <p>Any measure to reduce emissions effectively would run against current ways of life or human nature and is thus impossible to implement in a democratic society.</p>

## **Section B. Manual Coding of 20'000 tweets**

A random selection of 20'000 tweets from all scraped source tweets was manually coded by 4 trained and independent coders. Coders received a detailed coding manual and a verbal instruction. The first batch of 1000 tweets was coded by all 4 coders. Then, a joint meeting was held. Whenever two coders had a discrepancy in a coding, a discussion was held until a consensus for the correct codes was achieved. Based on the insights of how to best categorize different types of messages, the coding manual was updated.

The coding first involved to identify if the message was related to climate change at all. If not, the tweet was not further coded. The second step should identify if the tweet was understandable (yes/no). If not, the tweet was not further coded. If a tweet was sarcastic, it would also be rated as non-understandable.

Then, it was coded if the tweet contained any verifiable information on a 4-point Likert scale (1 = no verifiable information, e.g. opinion only, 4 = hard facts/numeric information that can be verified) and a first assessment of whether the tweet was correct (1 = not at all correct, 4 = very much correct). Note that for the messages that were ultimately included in the database and used as stimuli material, we employed a more scrutinous fact-checking afterwards where we verified with online literature research if the content was in line with the best available evidence. If a message contained some inaccurate or ambiguous claim, we wrote a debunking message that was shown to participants at the end of the study. This applied to a total of 8 out of 147 statements. The debriefing information is published alongside the full database online

(<http://pasa.psycharchives.org/reviewonly/0cafb27f10429473bf133e986659375f44780b118dafd4d9dd81f2c542249c75>).

In the next step, the content of the tweet was categorized. First, it was assessed whether the tweet was related to climate change (1), climate policies (and climate action; 2)

or both (3). Climate change arguments were categorized into one of five categories as shown in Table S1. Climate policy arguments were categorized into one of four categories and one of 12 sub-categories as listed in Table S2.

If a tweet was coded as climate related, understandable, verifiable (3 or 4), correct (3 or 4), it was then shortlisted for the *ClimateChirp* database. This resulted in a shortlist of 1105 tweets. To be finally included in the database, we then carefully revisited all shortlisted tweets and removed statements that were difficult to understand (because they contained scientific jargon) or contained specific references (e.g. to a local place or community, cultural references, references to specific politicians or scientists) that would make it more difficult to understand for audiences unfamiliar with these aspects (e.g. if it mentioned “Boris Johnson”, who might not be familiar to audiences outside of the U.K.) were also excluded. This led to 147 remaining Pro-climate messages that were included in the *ClimateChirp* database and used in the U.K. study.

For all of the messages included in the *ClimateChirp* database, we completed an additional round of fact-checking to test if the message was accurate and in line with the best available evidence. Most messages could indeed be verified, however, 9 of the messages contained exaggerated or somewhat misleading claims. We provide correcting information for each of these inaccurate statements in the database.

### Section C. UK Study: Study Materials

How many years of formal education have you completed?

- 0-6 (up to grade school/elementary school) (1)
- 7-12 (up to high school) (2)
- 13-16 (college/undergraduate university/certificate training) (3)
- More than 17 years (doctorate degree, medical degree, etc.) (4)
- Prefer not to answer (999)

Overall, how would you describe your political attitudes and beliefs?

*Please note, by "liberal" we mean classically left-wing, and by "conservative", we mean classically right-wing.*

	1	2	3	4	5	6	7	8	9	1	
very liberal/ left-wing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	very conservative/ right-wing

How much do you trust scientists to do what is right for your country?

- A lot (4)
- Some (3)
- Not too much (2)
- Not at all (1)

How important is the issue of global warming to you personally?

- Extremely important (1)
- Very important (2)
- Moderately important (3)
- Slightly important (4)
- Not at all important (5)

How worried are you about global warming?

- Very worried (1)
- Somewhat worried (2)
- Not very worried (3)
- Not at all worried (4)

How much do you think global warming will harm you personally?

- A great deal (1)
- A moderate amount (2)
- Only a little (3)
- Not at all (4)
- Don't know (5)

How much do you think global warming will harm future generations of people?

- A great deal (1)
- A moderate amount (2)
- Only a little (3)
- Not at all (4)
- Don't know (5)

**Statement Ratings** *[every question was presented on a separate page, the statement was shown on top of the page]*

How **understandable** do you find this statement?

- [1] not at all understandable
- [2]
- [3]
- [4]
- [5]
- [6] very well understandable

Are you **familiar** with the above statement (have you seen or heard it before)?

- No (1)
- Yes (0)
- Unsure (-1)

If you were to see the above statement **on social media**, how likely would you be to **share** it?

- [1] very unlikely
- [2]
- [3]
- [4]
- [5]
- [6] very likely

How does this statement make **you feel about climate action** (e.g. efforts to combat climate change and reduce carbon emissions)?

- [1] very much against it
- [2]
- [3]
- [4]
- [5]
- [6] very much in favor of it (6)

What is the likelihood that this **statement is true**?

- [1] Extremely unlikely
- [2]
- [3]
- [4]
- [5]
- [6] Extremely likely



#### **Section D. U.K. Study: Compare dropouts and completers**

Dropout participants rated an average of 2.4 out of 15 statements (contributing to 1.11% of all statement ratings), which we included in the data analysis. Excluding the dropouts from analyses did not change the results. However, dropout participants significantly differed from study completers in age (dropouts being on average 7 years older than study completers,  $t(38.9) = 3.03, p = .004$ ) and climate change views (dropouts rated climate change as less important and less worrying,  $t(32.94) = 2.67, p = .012$ ;  $t(32.19) = 2.6873, p = .011$ , respectively). There were no significant differences for gender, education, political attitude or expected harm of climate change between completers and dropouts (all  $p$ 's  $> .1$ ).

## **Section E. Comparison with Anti-climate message Ratings**

To assess whether the pro-climate statements were rated differently from anti-climate statements, we compared the results from the U.K study with the ratings from a similar, but independent study using by Spampatti et al. (2025).

**Participants and Procedure Anti-climate message study.** In that study, a representative sample of  $N = 500$  UK participants rated 10 randomly drawn statements from a pool of real-world Twitter messages that oppose climate change and climate action. Our procedures (including the retrieval of the stimuli material from Twitter, study procedure) closely followed Spampatti and colleagues (2025), precisely to allow us to compare the two samples. Below, we describe the deviations in the Anti-climate message study and the database generation.

### **Deviations between Anti- and Pro-climate message studies.**

For the Climate Disinformation Corpus (Spampatti et al. 2025), only the first author coded a random subset of 20000 tweets and there were no other coders involved. The source tweets did also include messages that were originally formulated in French, not only English-language tweets. The database generation is described in further detail by Spampatti and colleagues (2025).

For the studies, there were some deviations in the wording of the questions. Message importance was assessed with the question “*Assuming that the statement is entirely accurate, how important would this statement be?*”. It also included three questions how informative, manipulative and funny the messages were, that we did not include. Instead, the study did not assess the interestingness and hopefulness of the message. While most message ratings were also assessed on 6-point Likert scales, some were assessed on 7-pt or 10-pt Likert scales. Our study consistently used 6-point Likert scales for the message ratings. Wherever the scales deviated, we rescaled the responses to make them comparable.

**Table S3.** Descriptives for Message Ratings by representative samples from the UK for Anti-climate messages from the Climate Disinformation Corpus and for Pro-Climate Messages from the *ClimateChirp* Database

Rating Dimension	Mean		SD		Median	
	anti-climate messages	pro-climate messages	anti-climate messages	pro-climate messages	anti-climate messages	pro-climate messages
Importance	4.25	4.14	1.44	1.57	4.00	4.00
Share on Social Media	1.66	2.39	1.20	1.59	1.00	2.00
Likely True	2.89	4.19	1.57	1.41	3.00	4.00
Persuasive	2.68	3.58	1.50	1.62	2.67	4.00
Favorable for Conservatives	4.15	2.85	1.43	1.16	4.00	3.00
Outrage evoking	3.73	2.94	1.55	1.67	4.00	3.00
Worrying	2.85	3.46	1.65	1.68	3.00	4.00
Feeling positive about climate action	3.26	4.35	1.30	1.43	3.22	4.00
Familiar (Yes)	0.12	0.25	0.07	0.17	0.11	0.20
Familiar (No)	0.77	0.65	0.09	0.18	0.78	0.68
Familiar (Unsure)	0.11	0.10	0.04	0.05	0.11	0.10

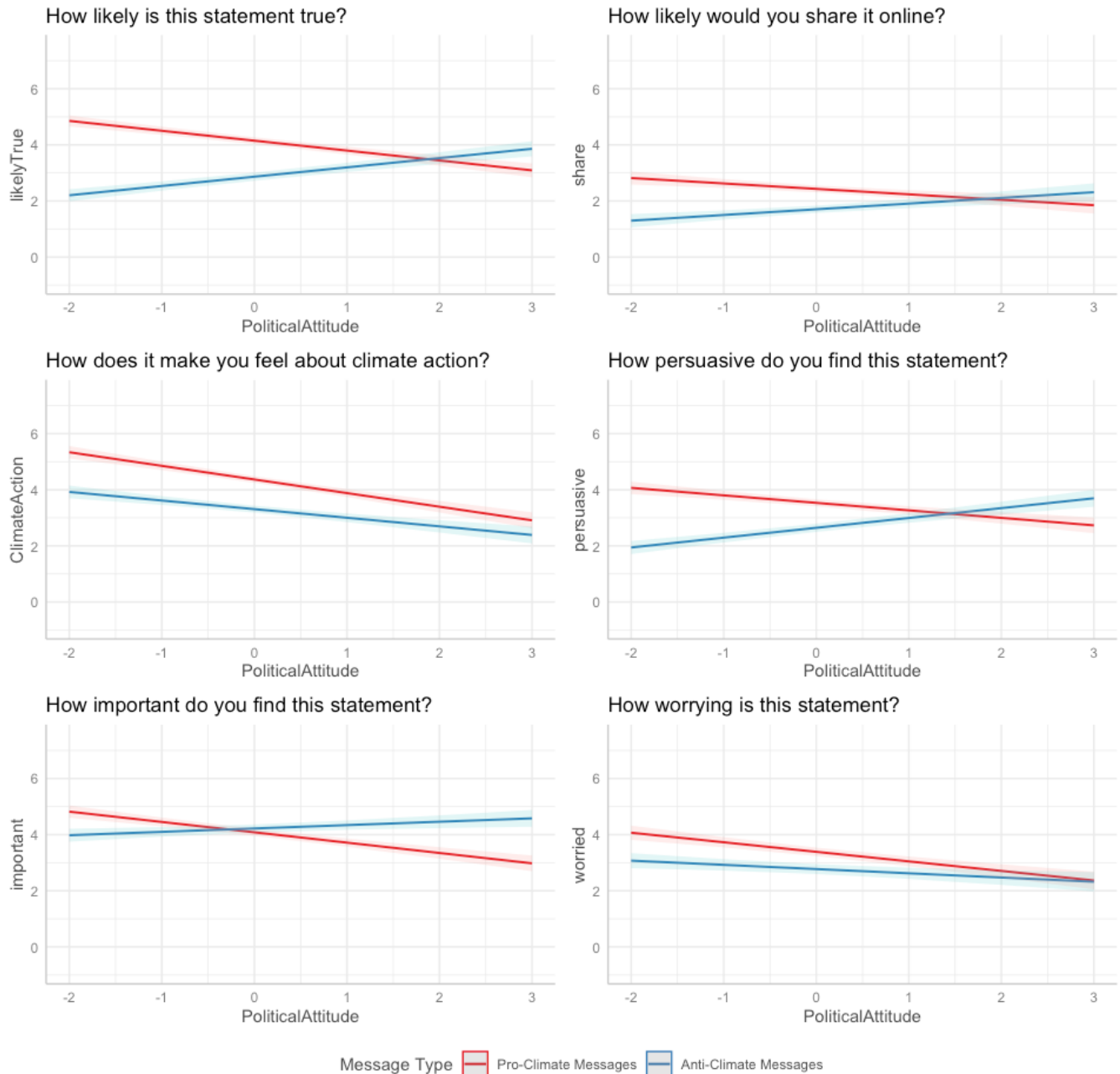
## **Discriminant validity in Disinformation vs. Information Stimuli**

To assess whether the pro-climate statements were perceived as substantially different from the anti-climate statements, we coupled the data from the U.K. study with data from the disinformation study by Spampatti et al. (2025).

Overall, the pro-climate messages were on average rated as more likely to be true, more persuasive, more worrying, more familiar and evoked higher sharing intentions on social media, and participants reported to be more in favor of climate action (all Bonferroni-adjusted  $p$  values in independent  $t$ -test comparisons  $\leq .001$ ; Cohen's  $d$ s ranged from  $d = 0.37$  for worrying to  $d = 0.87$  for likely true). The anti-climate messages were rated as significantly more outrage-evoking ( $d = -0.49$ ) and as more favorable to Conservatives ( $d = -1.00$ ) on average. See Table S3 for means and standard deviations of ratings.

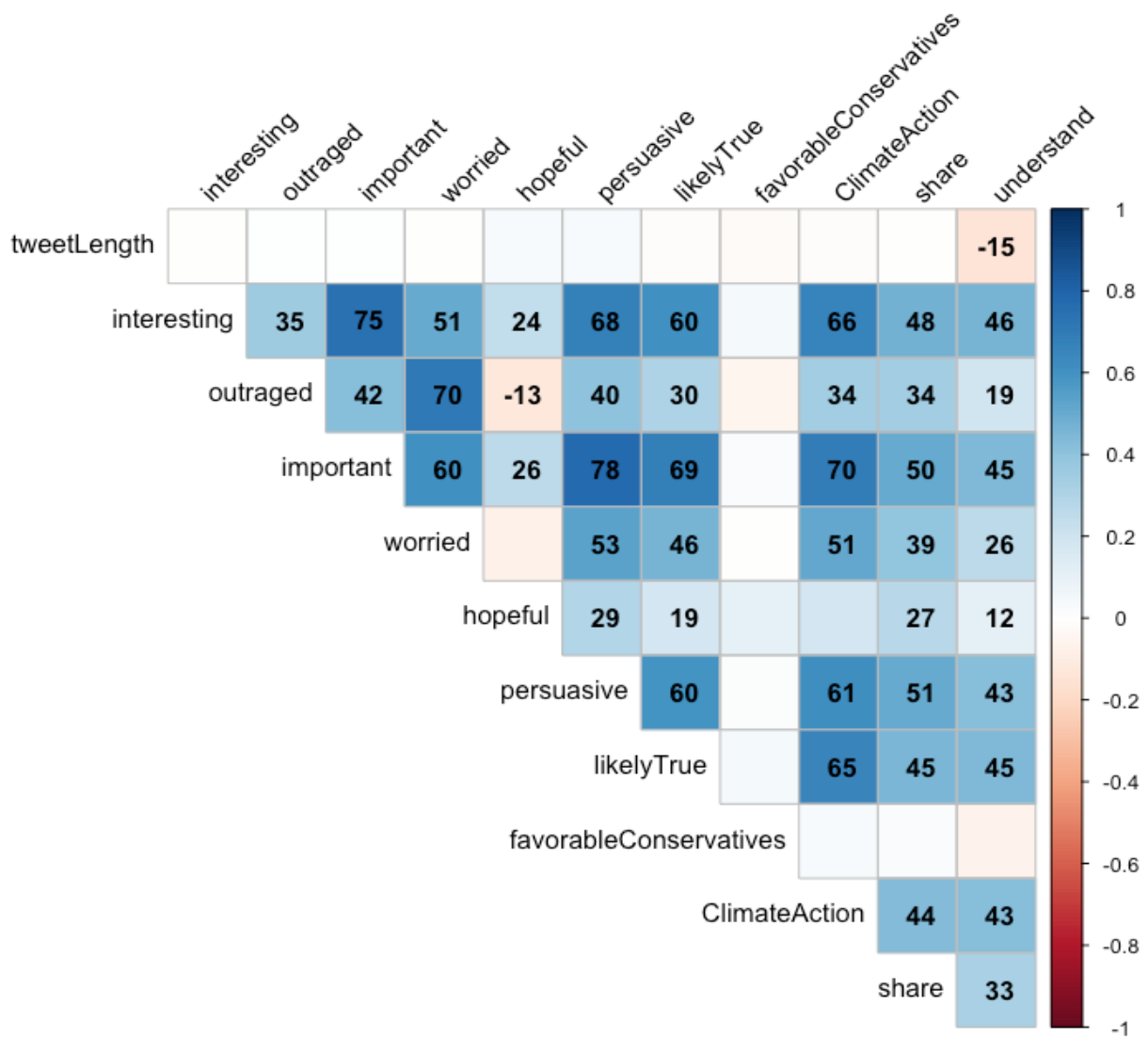
We also tested if patterns of message ratings differed by political orientation. This would speak to a discriminant validity of the pro-climate stimuli, showing that relationships between political orientation and message ratings would reverse for pro- compared to anti-climate messages. For this, we computed mixed effects multilevel regression models with independent random intercepts for participant and statement ID and controlling for the effects of age, gender and education to test for the effect of statement source (i.e. a message from the pro- or anti-climate database), political attitude and their interaction on statement ratings. The rating dimensions were importance, worry, truth, persuasiveness, sharing intentions and feelings about climate action. The analyses confirmed significant and positive interactions between statement source and participant political attitude, as depicted in Figure S1 (all  $p$ 's  $< .006$ , reversed interactions for likely true ratings, sharing intentions, important, persuasiveness and worried and attenuated interactions for feelings about climate action and worried). This indicated that more left-leaning participants rated pro-climate statements higher on these dimensions than more right-leaning participants, but this relationship was attenuated or reversed for anti-climate statements. For instance, the pro-climate statements

were rated as more likely to be true on average, regression weight for main effect of statement source  $\beta = 1.28$ , 95% CI [1.11, 1.46],  $t(12464) = -14.51$ ,  $p < .001$ . However, for very conservative/right-wing participants (z-standardized), this pattern reversed, with higher likely true ratings for anti-climate statements, regression weight for the interaction term  $\beta = 0.68$ , 95% CI [0.58, 0.79],  $t(12464) = 12.95$ ,  $p < .001$  (cf. Figure S1). For the worry-ratings, liberal participants indicated overall higher levels of worry ( $\beta = -0.34$ , 95% CI [-0.44, -0.24],  $t(12458) = -6.94$ ,  $p < .001$ ) and an attenuated interaction occurred where liberal participants found pro-climate statements more worrying than the anti-climate statements while this difference vanished for conservative participants ( $\beta = 0.19$ , 95% CI [0.05, 0.33],  $t(12458) = 2.74$ ,  $p = .006$ , cf. Figure S1). This underscores that Pro- and Anti-climate statements conveyed qualitatively different messages that were also perceived differently by participants.



**Figure S1. Divergent Validity of Pro- and Anti-climate messages.** Predicted attribute ratings from linear mixed effects by statement category (Pro- vs. Anti-climate) and political orientation of participant. Political orientation is z-standardized. Shaded areas show the 95% confidence intervals of the regression models. The high mean importance ratings for the Anti-climate statements are because a different question wording was used. Participants in the Anti-climate database validation study were asked “Assuming that the statement is entirely accurate, how important would this statement be?”.

## Section F. Supplementary Analyses



**Figure S2. Correlation Plots for Statement Ratings.** Itemwise correlation between message statement ratings on different dimensions. Correlation coefficients written in black are significant at the  $\alpha = .05$  level. Only first two decimal points of the correlation coefficients are shown for better readability, i.e. -15 indicates  $r = -0.15$ .

## Factor Analysis for Message Ratings

As preregistered, we computed a confirmatory factor analysis for the message ratings using 3 factors to test if we can replicate the factor structure by Chen, Pennycook & Rand (2023). The authors suggested a three-factor structure with factors with perceived accuracy, evocativeness and familiarity. We used the R-package lavaan to test the fit of this factor analysis (Rosseel, 2012). However, the message ratings used for our studies slightly deviated from the items used by Chen et al. (2023) and the resulting model fit was very poor (CFI = 0.449, RSMEA = 0.323)

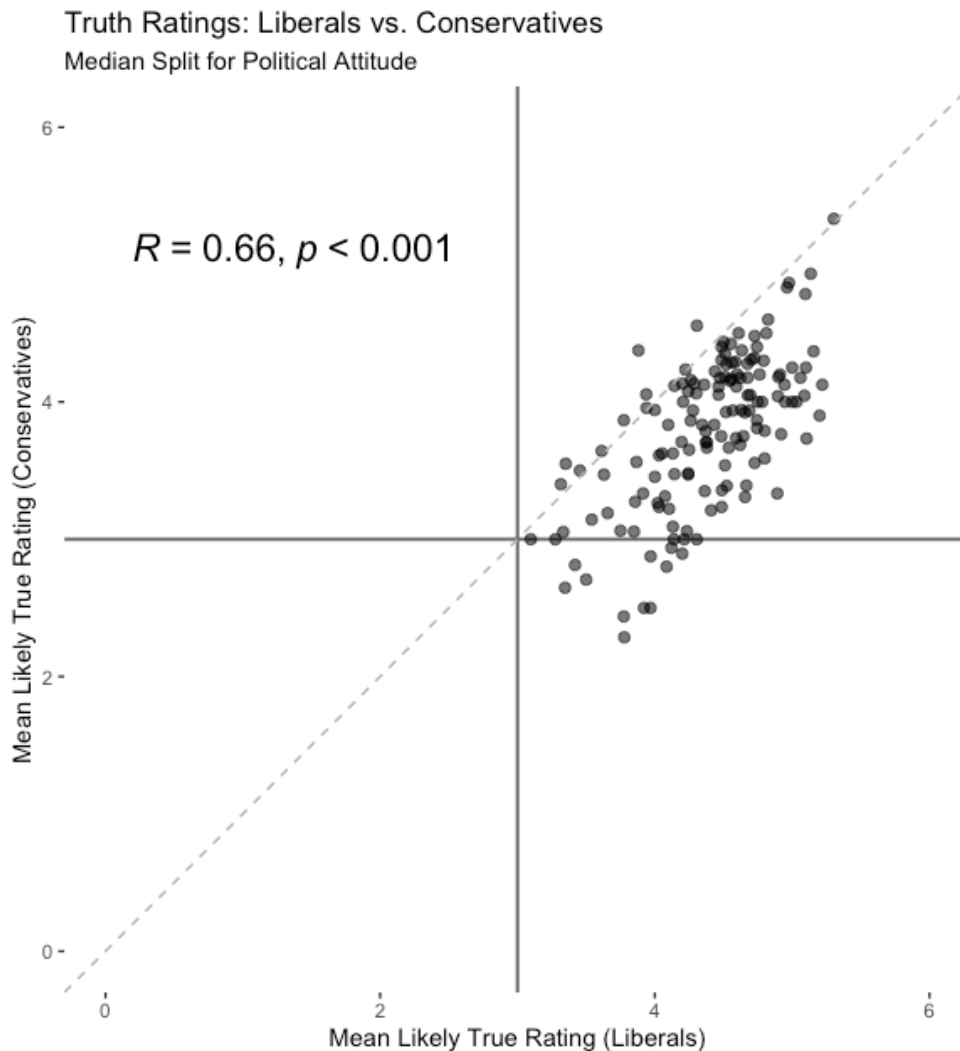
Therefore, we instead computed an exploratory factor analysis. For this, we first computed a Principal Component Analysis (PCA) and used a scree plot to assess what number of factors would be most appropriate. Both analyses suggested that two factors would be a reasonable choice.

We used principal axis factoring with an oblimin rotation, to allow for covariance between the extracted factors. The two-factor model provided a good fit to the data, explaining 53% of the total variance in the items. The model fit indices were acceptable, with a Tucker-Lewis Index (TLI) of 0.93 and a root mean square of the residuals (RMSR) of 0.04. The two factors were positively correlated ( $r = .53$ ), suggesting that messages perceived as having a stronger negative emotional valence were also rated as more effective. Table S3 shows the factor loadings of every rating dimension on the two extracted factors as well as its commonality ( $h^2$ ) and uniqueness ( $u^2$ ).

**Table S3.** Pattern Matrix of Factor Loadings from Exploratory Factor Analysis

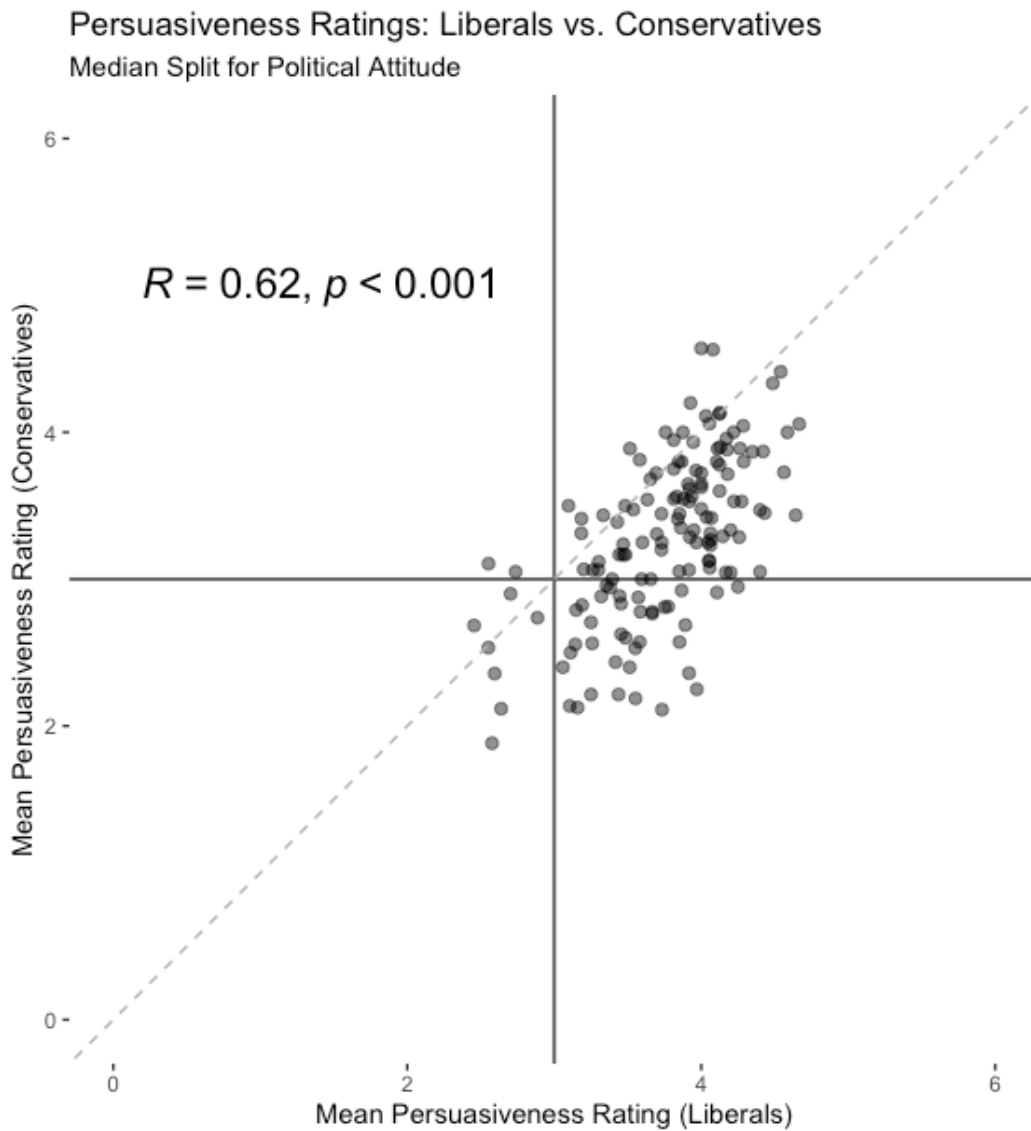
	<b>Factor Loadings</b>		<b>h2</b>	<b>u2</b>
	<b>Effectiveness (PA1)</b>	<b>Negative Emotion (PA2)</b>		
interesting	0.81		0.67	0.33
familiar			0.09	0.91
outraged		0.79	0.63	0.37
important	0.85		0.80	0.20
worried		0.79	0.82	0.18
hopeful	0.55	-0.45	0.24	0.76
persuasive	0.8		0.68	0.32
likelyTrue	0.76		0.59	0.41
ClimateAction	0.74		0.60	0.40
share	0.58		0.37	0.63
understand	0.57		0.29	0.71

### Heterogeneity in Message Ratings, Audience effects by political subgroup and agreement in relative message ranking



**Figure S3. Heterogeneity in Truth Ratings.** Variability in Mean Likely True Ratings for every message by political participant subgroups (Liberal vs. Conservative subgroups)

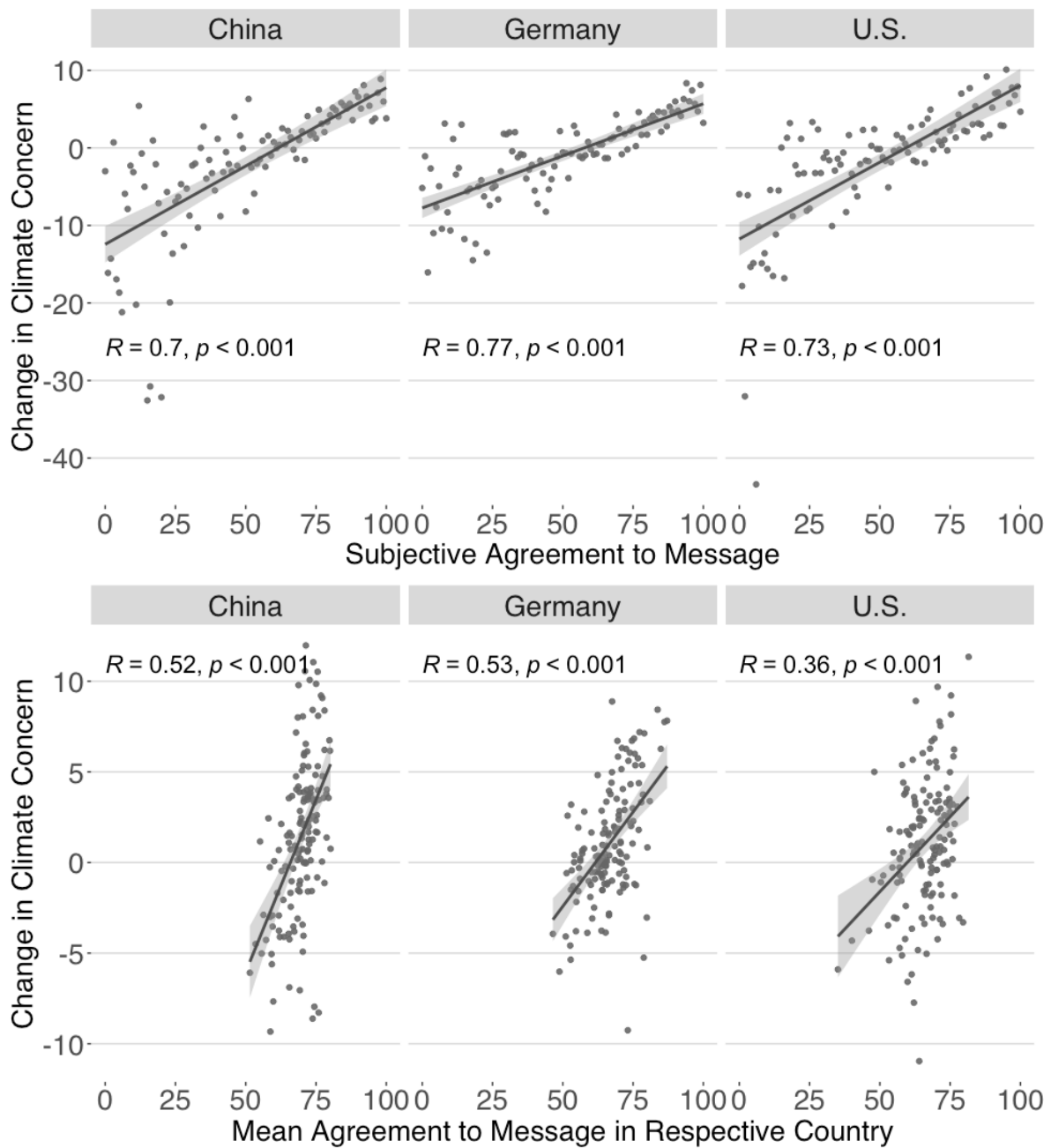
*Note.* Every point indicates one of message describe by the likely-true mean rating from politically liberal participants (x-axis) and politically conservative participants (y-axis). Dashed line is identity line, if liberal and conservative participants perfectly agreed on the ratings. High correlation shows the agreement between political groups in the ranking of the messages.



**Figure S4. Heterogeneity in Persuasiveness Ratings.** Variability in Mean Persuasiveness Ratings for every message by political participant subgroups (Liberal vs. Conservative subgroups)

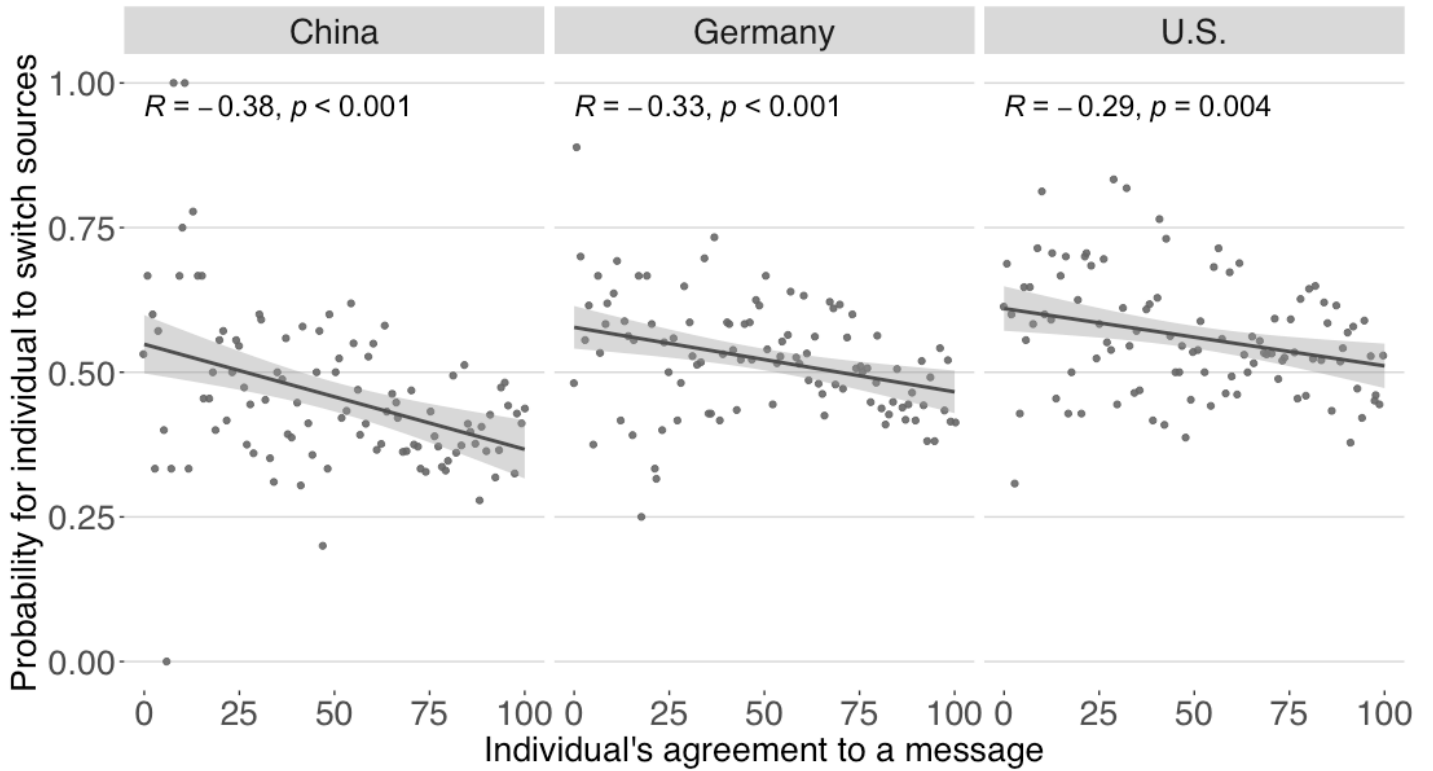
*Note.* Every point indicates one of message describe by the persuasiveness mean rating from politically liberal participants (x-axis) and politically conservative participants (y-axis). Dashed line is identity line, if liberal and conservative participants perfectly agreed on the ratings. High correlation shows the agreement between political groups in the ranking of the messages.

**Predicting Changes in Momentary Climate Concern from Individual (Subjective) and Mean Agreement in three countries**



**Figure S5.** Predicting changes in climate concern from participants' agreement to a message. Upper panel: In all three countries, the more a participant agreed with a message, the more they also indicated climate change concern above their baseline climate concern. Note that climate concern was within-person-centered, that is average climate concern for all participants was 0 (the consistently higher values than zero results from the fact that momentary climate change concern was significantly lower after reading an anti-climate message, which is not plotted here). Lower panel: Mean agreement to a message in the respective country predicts changes in within-person centered climate concern.

## Predicting Information Search Behavior and Change in Concern from Individual (Subjective) Agreement



**Figure S6.** Predicting source switching from participants' agreement to previous message. In all three countries, the more a participant agreed with a message, the more likely they are to keep sampling from the same source (not switch to the climate contrarian disinformation source).