Evidence for three distinct climate change audience segments with varying belief updating tendencies: Implications for climate change communication

Matthew Andreotta [*1,2], Fabio Boschetti[3], Simon Farrell[1], Cecile Paris[2], Iain Walker[4] and Mark Hurlstone[5]

[1]School of Psychological Science, University of Western Australia, Perth, Australia

[2]Data61, Commonwealth Scientific and Industrial Research Organisation, Sydney, Australia

[3]Oceans and Atmosphere, Commonwealth Scientific and Industrial Research Organisation, Perth, Australia

[4]Research School of Psychology, Australian National University, Canberra, Australia

[5]Department of Psychology, Lancaster University, Lancaster, United Kingdom

[*]Corresponding author address: 35 Stirling Highway, Perth, WA, 6009; phone: (+61 8) 6488 3245; email: matthew.andreotta@research.uwa.edu.au

Abstract

Mounting evidence suggests the general public is not homogeneous in their receptivity to climate science information. Studies segmenting climate change perceptions typically deploy a top-down approach, whereby concepts salient in scientific literature determine the number and nature of segments. In contrast, in two studies using Australian citizens, we used a bottom-up approach, in which segments were determined from perceptions of climate change concepts derived from citizen social media discourse. In Study 1, we identified three segments of the Australian public (Acceptors, Opaque, and Sceptics) and their psychological characteristics. We find segments differ in climate change concern and scepticism, mental models of climate, political ideology, and worldviews. In Study 2, we examined whether reception to scientific information differed across segments using a belief-updating task. Participants were first asked their beliefs related to contribution of different causes to climate change, the likelihood climate change will have specific impacts, and the effectiveness of Australia's mitigation policy, and then provided with the actual scientific estimates for each event. We find significant heterogeneity in the belief-updating tendencies of the three segments that can be understood by recourse to their different psychological characteristics. Our results suggest tailored scientific communications informed by the psychological profiles of different segments may be more effective than a 'one-size-fits-all' approach to scientific communication. Using our novel audience segmentation analysis, we provide some practical suggestions of how communication strategies can be improved by accounting for segments' characteristics.

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In 2016, the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC) was ratified. Parties to the agreement have pledged to cooperate to keep global temperature increases well below 2 degrees Celsius above pre-industrial levels (UNFCCC, 2018). The continued cooperation of democratic countries is partly determined by public support. Yet, public concern for climate change lags behind other social issues, such as crime and health care (Hagen et al., 2016; Lorenzoni & Pidgeon, 2006; Nisbet & Myers, 2007).

Various interventions have been proposed to increase support for climate policy. For example, telling people the proportion of climate scientists who believe in anthropogenic climate change (97%)—known as consensus messaging—increases belief in, and concern about, anthropogenic climate change, which, in turn, enhances policy support (van der Linden et al., 2015; van der Linden, in press). Such interventions treat the public as a homogeneous entity. However, reception to climate change messages can differ due to differences in motivation, ideology, and worldview (Feygina et al., 2010; Kahan, 2012). For example, Hart and Nisbet (2012) exposed Americans to a news story describing climate change risks, before measuring support for mitigation policies. Compared to controls not exposed to an article, liberals who read the news story showed greater support for mitigation policy, whereas conservatives showed reduced support. Thus, when climate change messages clash with a person's pre-existing political beliefs, they can potentially backfire.

To improve interventions, communicators may use *audience segmentation* techniques to divide the public into homogeneous groupings (W. R. Smith, 1956). Messages can then be tailored to the characteristics of each group, which may enhance communication effectiveness and mitigate the risk of backfire effects (Corner & Randall, 2011). A meta-analysis of health communication suggests segmentation approaches are more effective than a 'one-size-fits-all' approach, particularly when psychological theory is used to understand each segment (Noar et al., 2007).

Perhaps the most established audience segmentation for climate change communication is the *Six Americas* (Maibach et al., 2011; Yale Program on Climate Change Communication, 2020). Six homogeneous groups were developed from the responses of a nationally representative survey of Americans. Although multidimensional, the Six Americas may be ordered on continuous dimensions of belief and concern about climate change. The segments range from the 'alarmed', a community most accepting of climate change science; via the 'concerned'; the 'cautious'; the 'disengaged'; the 'doubtful'; to the 'dismissive', a community which rejects climate science. However, segments that differ in their concern about climate change are similar on other dimensions. For example, the 'alarmed' and the 'dismissive' are unified in their self-reported unwillingness to change their own opinions (Maibach et al., 2011). Conceptual replications and kindred studies reveal comparable segments in other nations, such as Australia (Hine et al., 2013; Morrison et al., 2013) and Germany (Metag et al., 2017). By integrating segment characteristics with psychological theory, the Yale Program for Climate Change Communication has provided guidelines for tailoring communication to each segment (Roser-Renouf et al., 2015).

Most climate change audience segments, including the Six Americas, are developed following a *top-down* approach. Specifically, the audience is assessed across a myriad of constructs known to correlate with climate change perceptions, policy support, and pro-environmental behaviour (for a review, see Hine et al., 2014). Participants are then grouped using statistical techniques (e.g., Latent Class Analysis). By contrast, in a *bottom-up* approach the content on which an audience is assessed emerges from an analysis of the features of climate change discourse expressed by the public. This overcomes a disadvantage of top-down approaches—they may omit features of climate change salient to the public, but not researchers. However, bottom-up approaches are currently sorely lacking in the climate change domain. Thus, it is unknown to what degree current understandings of segmentation are limited by researcher's preconceived notions of theory. Here we addressed this shortcoming using a bottom-up audience segmentation approach. Complementarily, we used a top-down

approach to facilitate segment interpretation by incorporating auxiliary measures of psychological constructs that may account for differences in segment membership. Critically, these auxiliary measures were used to help interpret audience segments after they had been derived—they did not contribute to the segmentation process itself.

The current paper pursued bottom-up segmentation using the *Q methodology*—an analytical approach dedicated towards meaningful representation of participants' views (Brown, 1980). The data collection procedure uses a Q sort task whereby participants rank statements about a topic, usually along a dimension of agreement. Statements are often generated using a bottom-up approach, where the statements capture the breadth of conversational possibilities (Brown, 1980; Stephenson, 1986). Participants are then segmented based on the ranks assigned to statements using factor-analytic approaches.

Applications of the Q methodology to climate change audiences are rare and limited to small non-representative samples (e.g., Hobson & Niemeyer, 2012; Wolf et al., 2009). The current research is the first to apply the Q methodology to nationally representative samples. The statements used were derived from our previous work, which identified the persistent topics of Australian climate change discourse on social media (Andreotta et al., 2019). Although social media data does not contain an exhaustive set of conversational topics, it serves as a reasonable compromise between analyses of documents written by specific subgroups of the population (e.g., news articles written by journalists) and a prohibitively expensive study that interviews hundreds of citizens. Therefore, the statements used in the Q methodology allowed participants to express their viewpoint in terms of the diversity of opinions embodied in popular public discourse on climate change.

To facilitate interpretation of audience segments derived using the Q methodology, we incorporated auxiliary measures of several potentially relevant psychological constructs that may help explain differences between segments. In particular, we consider the *mental model*—internalised representations of a phenomenon that individuals use to generate descriptions, explanations, and predictions (Granger

et al., 2002; Jones et al., 2011; Rouse & Morris, 1986). Different mental models can generate different predictions (Gentner & Gentner, 1983). To illustrate, consider two mental models identified by previous research: the first model features greenhouse gas emissions as the predominant cause of climate change, whereas the second model features toxic air pollution as the predominant cause (Kempton et al., 1995; Reynolds et al., 2010). Individuals with the second model may be more likely than individuals with the first to suggest the counterproductive strategy of mitigating climate change by additional filtering of factory smokestacks (Kempton et al., 1995). Thus, knowledge of audience's mental models provides insight into the logic by which trusted information will be transformed into action or knowledge (Granger et al., 2002), and which policies may be endorsed over others (Bostrom et al., 2012).

In addition to mental models, climate change views are influenced by various psychological factors (Swim et al., 2009). For example, individuals may be motivated to reject anthropogenic climate change because they: engage in conspiracist ideation (Lewandowsky et al., 2013); have a worldview that the environment is elastic and resilient to change (Price et al., 2014); are politically conservative (Leiserowitz, 2006); sceptical of societies capacity to avert climate change (Capstick & Pidgeon, 2014); exhibit justification for the status-quo (Feygina et al., 2010); and value conserving oneself and society. In contrast, individuals who value self-transcendence, are worried about climate change, and have a worldview that the environment is ductile and sensitive to change may be more likely to support mitigative policy (Corner et al., 2014; Price et al., 2014; N. Smith & Leiserowitz, 2014). Other potentially relevant factors include personality (Yu & Yu, 2017), consideration of future consequences (Wang, 2017), self-perceived level of climate change knowledge (Stoutenborough & Vedlitz, 2014), and need for cognition (Sinatra et al., 2014). The current paper examined segment differences in these psychological constructs.

Next, we present two studies using representative samples of the Australian public. Study 1 sought to derive audience segments using a bottom-up approach—namely, a Q methodology using statements derived from social media

discourse. In addition to the Q sort task, participants completed measures of the foregoing psychological constructs to help identify the psychological underpinnings of the emergent segments. The study revealed evidence for three different segments: the Acceptors, Opaque, and Sceptics. Auxiliary variable analysis revealed segments differed in their mental models, climate change concern and scepticism, political ideology, and environmental worldviews. In Study 2, we sought to replicate our three-segment and establish if segments differed in their receptivity to climate science information. Participants completed a belief-updating task in which they were asked their beliefs about the contribution of different causes to climate change, the likelihood climate change will have specific impacts, and the effectiveness of Australia's mitigation policy. They were then given the actual scientific estimates for each event before submitting their revised belief estimates. We replicated the three-segment solution of Study 1 but additionally showed there was considerable heterogeneity across segments in their belief-updating tendencies. These results provide insights into the effectiveness of communicating scientific information to each segment.

Study 1

The aims of this study were to segment the audience using a bottom-up approach and determine segment differences across a range of psychological constructs. The psychological constructs—and the measurement scales used to tap them—were selected using three criteria: (1) sampling constructs from as much theoretical space as possible; (2) sampling scales with good psychometric properties (reliability and validity); and (3) pragmatic constraints that lead us to minimise conceptual overlap of constructs and select short-form scales when possible. The literature search yielded 28 psychological constructs, described next.

Method

This study was pre-registered using the Open Science Framework (https://osf.io/e7zhx/). For both studies, the materials, data, and analysis scripts are available at https://github.com/AndreottaM/MM-audience-segmentation. The studies

were approved by the University of Western Australia Human Research Ethics Office (RA/4/20/5104), and reciprocated by the Commonwealth Scientific and Industrial Research Organisation Human Research Ethics Committee (026/19).

Participants. Four-hundred and thirty-five Australian adults were recruited online by Qualtrics. A targeted and stratified sampling process was used, whereby the age ($M = 46.71$, $SD = 17.77$) and gender (female = 50.34%) were matched to the general population of Australian adults reported in the national 2016 census.

Materials and Procedure. Participants completed the Q sort followed by an inventory of psychological constructs. Administration of survey scales was counterbalanced to control order effects (see Supplementary Material).

Q sort. The Q sort requires a set of statements capturing the breadth of conversational possibilities of an issue (Stephenson, 1986). To this end, we used an inductive process to identify the structure of climate change commentary using a data set of Australian tweets (Andreotta et al., 2019). We identified five enduring themes of public discourse on climate change: climate change action, climate change consequences, climate change conversations, climate change denial, and the legitimacy of climate science and climate change. For each theme, we selected six tweets that captured the heterogeneity of the theme (see Supplementary Materials). The resulting 30 tweets were transcribed as statements that could be understood without the social context of the original tweet. Where possible, language, sentiment, and tone were preserved. Statements included: "it is important to vote for leaders who will combat climate change" (climate change action), "climate change is a threat to the health and safety of our children" (climate change consequences), "it is shameful that climate change, the greatest problem of our time, is barely discussed in the media" (climate change conversations), "climate change sceptics ignore basic climate science facts" (climate change denial), and "scientists should stop falsely claiming that climate change is a settled science" (legitimacy of climate science and climate change).

The Q sort comprised three phases. In phase one, participants read each statement and indicated whether it was like their point of view, unlike their point of

view, or whether they were neutral or unsure. Statements were presented in a fixed but random order. This initial phase familiarized participants with the statements. Phase two required participants to rank statements from "most unlike my point of view" (-4) to "most like my point of view" (+4). The number of statements that could be placed at each rank was predetermined, such that more statements could be placed at the midpoint than more extreme ranks (Figure 1). In phase 3, participants responded to open-ended questions prompting them to justify their placement of the statements ranked most extreme (that is, at positions +4 and -4).

Scales. Twenty-eight scales were used to measure various psychological constructs. For brevity, the scales and constructs are summarised in Table 1 (see Supplementary Materials for more detail). When required, scales were adapted to refer to Australia instead of America.

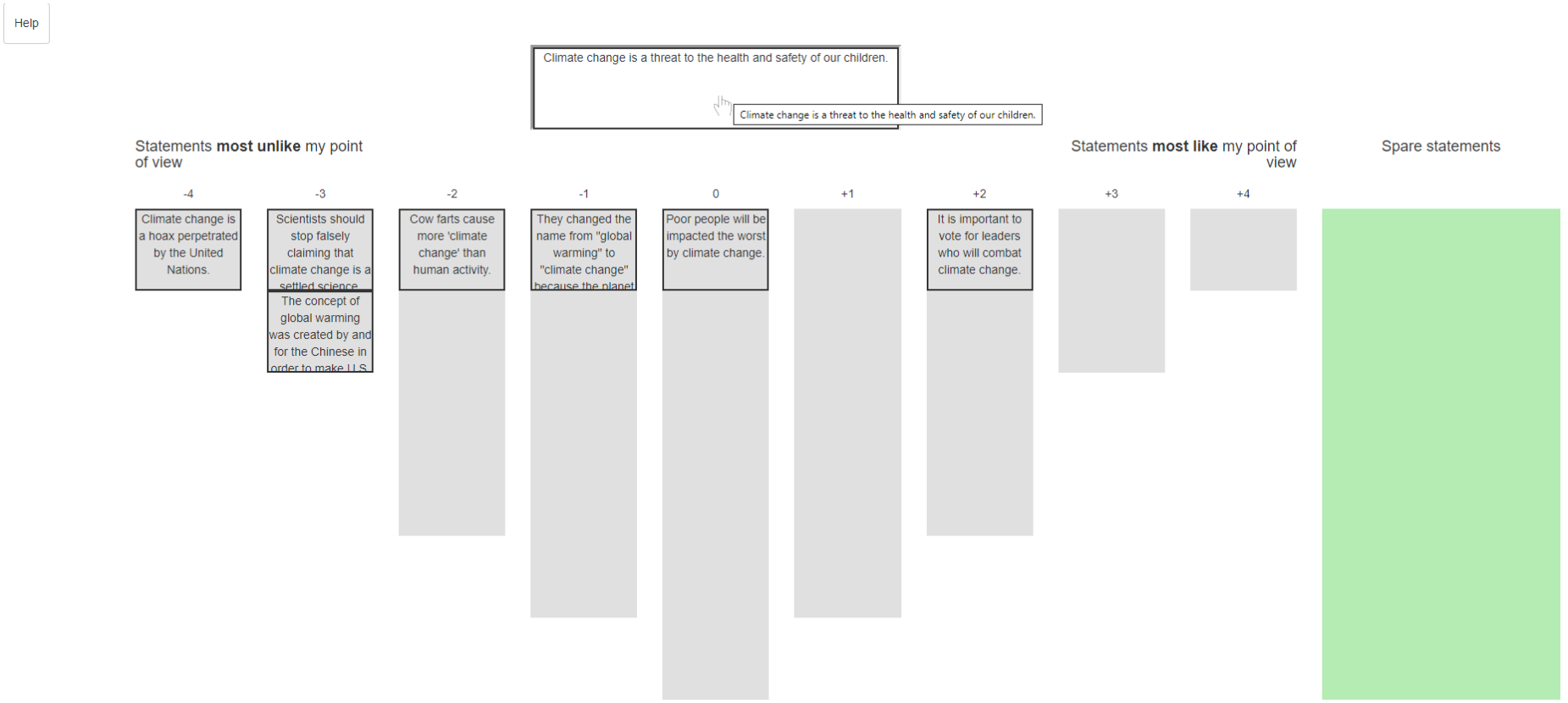

Figure 1. The Q sort interface. Participants dragged each statement into a position on the grid (grey). A quasi-gaussian distribution was enforced, such that the majority of statements must be placed around the midpoint. Participants could move statements once placed. To facilitate this process, a temporary holding area was provided (green).

Table 1

Summary of survey measures used in Study 1.

Abbreviation	Construct	Items	Cronbach's α	Range	Example	Scale
BFI_A	Agreeableness	2	0.26	1-5	I see myself as someone who is generally trusting	Big Five Inventory-10 (Rammstedt & John, 2007)
BFI_C	Conscientiousness	2	0.55	1-5	I see myself as someone who does a thorough job	Big Five Inventory-10 (Rammstedt & John, 2007)
BFI_E	Extraversion	2	0.50	1-5	I see myself as someone who is outgoing, sociable	Big Five Inventory-10 (Rammstedt & John, 2007)
BFI_N	Neuroticism	2	0.66	1-5	I see myself as someone who gets nervous easily	Big Five Inventory-10 (Rammstedt & John, 2007)
BFI_O	Openness	2	0.21	1-5	I see myself as someone who has an active imagination	Big Five Inventory-10 (Rammstedt & John, 2007)
CFC_F	Orientation to future goals	4	0.71	1-5	I consider how things might be in the future	Consideration of Future Consequences (Enzler, 2015)
CFC_I	Orientation to immediate goals	5	0.86	1-5	I mainly act to satisfy my immediate concerns, figuring the future will take care of itself	Consideration of Future Consequences (Enzler, 2015)

Table 1

Summary of survey measures used in Study 1. (continued)

Abbreviation	Construct	Items	Cronbach's α	Range	Example	Scale
CI	Conspiratorial Ideation	6	0.88	1-5	The Apollo moon landings never happened and were staged in a Hollywood film studio	Conspiracist Ideation (Lewandowsky et al., 2013)
EWS_D	Environment as Ductile Worldview	6	0.81	1-5	If the balance of the natural environment is upset the whole system will collapse	Environmental Worldview Scale (Price et al., 2014)
EWS_E	Environment as Elastic Worldview	6	0.85	1-5	The natural environment is capable of recovering from any damage humans may cause	Environmental Worldview Scale (Price et al., 2014)
KV	Knowledge Volume	1	na	1-4	How much do you feel you know about climate change?	Knowledge Volume (Malka et al., 2009)
MMS_CAU_C	Perceptions of Carbon Emission Causes of Climate Change	7	0.92	1-7	Please indicate to what extent each of the following is a cause of climate change, to the best of your knowledge: people driving their cars	Based on Mental Model Scale (Subscale: Perceived Causes of Climate Change; Bostrom et al., 2012)
MMS_CAU_E	Perceptions of Environmental Harm Causes of Climate Change	4	0.87	1-7	Please indicate to what extent each of the following is a cause of climate change, to the best of your knowledge: air pollution from toxic chemicals	Based on Mental Model Scale (Subscale: Perceived Causes of Climate Change; Bostrom et al., 2012)

Table 1

Summary of survey measures used in Study 1. (continued)

Abbreviation	Construct	Items	Cronbach's α	Range	Example	Scale
MMS_CAU_N	Perceptions of Natural Causes of Climate Change	2	0.77	1-7	Please indicate to what extent each of the following is a cause of climate change, to the best of your knowledge: volcanic eruptions	Based on Mental Model Scale (Subscale: Perceived Causes of Climate Change; Bostrom et al., 2012)
MMS_CON_P	Perceived Personal Consequences of Climate Change	3	0.89	1-7	Please rate for each of the following how likely it is as a consequence of climate change by the year 2050: food shortages where you live	Mental Model Scale (Subscale: Perceived Consequences of Climate Change; Bostrom et al., 2012)
MMS_CON_S	Perceived Societal Consequences of Climate Change	8	0.96	1-7	Please rate for each of the following how likely it is as a consequence of climate change by the year 2050: food shortages in many parts of the world	Mental Model Scale (Subscale: Perceived Consequences of Climate Change; Bostrom et al., 2012)
MMS_HUM	Perceived Human Contribution to Climate Change	1	na	1-7	How likely do you think it is that human actions have changed global climate?	Mental Model Scale (Subscale: Human Contribution; Bostrom et al., 2012)

Table 1

Summary of survey measures used in Study 1. (continued)

Abbreviation	Construct	Items	Cronbach's α	Range	Example	Scale
MMS_MIT_C	Perceived Effectiveness of Carbon Policies	3	0.74	1-7	Please rate for each step what effect you think it would have on climate change: requiring cars and trucks to have higher fuel efficiency (1 = Reduce or Stop Climate Change, 4 = Neither Reduce nor Increase, 7 = Increase Climate Change)	Mental Model Scale (Subscale: Perceived Effectiveness of Mitigative Action Policies; Bostrom et al., 2012)
MMS_MIT_E	Perceived Effectiveness of Green Policies	5	0.40	1-7	Please rate for each step what effect you think it would have on climate change: planting trees (1 = Reduce or Stop Climate Change, 4 = Neither Reduce nor Increase, 7 = Increase Climate Change)	Mental Model Scale (Subscale: Perceived Effectiveness of Mitigative Action Policies; Bostrom et al., 2012)
MMS_MIT_G	Perceived Effectiveness of Engineering Policies	3	0.91	1-7	Please rate for each step what effect you think it would have on climate change: putting more dust in the atmosphere (1 = Reduce or Stop Climate Change, 4 = Neither Reduce nor Increase, 7 = Increase Climate Change)	Mental Model Scale (Subscale: Perceived Effectiveness of Mitigative Action Policies; Bostrom et al., 2012)

Table 1

Summary of survey measures used in Study 1. (continued)

Abbreviation	Construct	Items	Cronbach's α	Range	Example	Scale
NCS	Need for Cognition	6	0.80	1-5	I would prefer complex to simple problems	Need for Cognition Scale (NCS-6) (Lins de Holanda Coelho et al., 2018)
PI	Political Ideology	1	na	1-7	Please indicate the extent to which you identify yourself as politically left-wing or right-wing (1 = Very Left-Wing, 7 = Very Right-Wing)	na
SJ	System Justification	8	0.86	1-9	Everyone has a fair shot at wealth and happiness	System Justification Scale (Kay & Jost, 2003)
SS_E	Epistemic Scepticism	8	0.91	1-5	Climate change is just a natural fluctuation in Earth's temperatures	Items from Capstick and Pidgeon (2014)
SS_R	Response Scepticism	7	0.89	1-5	There is no point in me doing anything about climate change because no-one else is	Items from Capstick and Pidgeon (2014)
SVSS_C	Conservation Values	10	0.63	-2.94-5.54	Please, rate the importance of the following values as a life-guiding principle for you: CONFORMITY (obedience, honouring parents and elders, self-discipline, politeness)	Short Schwartz Value Scale (Lindeman & Verkasalo, 2005)

Table 1

Summary of survey measures used in Study 1. (continued)

Abbreviation	Construct	Items	Cronbach's α	Range	Example	Scale
SVSS_ST	Self-Transcendence Values	10	0.69	-4.84-2.52	Please, rate the importance of the following values as a life-guiding principle for you: BENEVOLENCE (helpfulness, honesty, forgiveness, loyalty, responsibility)	Short Schwartz Value Scale (Lindeman & Verkasalo, 2005)
W	Worry about Climate Change	1	na	1-4	How strongly do you feel worry when you think about the issue of climate change?	Item from Emotion Scale (N. Smith & Leiserowitz, 2014)

Note: Pilot testing indicate the Perceived Causes of Climate Change subscale of Bostrom et al. (2012) required an additional item to capture perceptions of natural causes (see Supplementary Material). All items of the Perceived Effectiveness of Mitigative Action subscale of the Mental Model Scale were reverse scored. The *range* indicates the minimum and maximum score of a construct. For the Short Schwartz Value Scale, Conservation and Self-transcendence scores were calculated as a composite score of ten values (each of which was rated along a nine-point scale).

Results and Discussion

Segments. The Q sort data was used to identify a segmentation solution for the sample. Factor analysis was conducted to identify factors of *individuals* who sorted statements in a similar fashion. Participants who have the same signed loading on the same factor share a common viewpoint (Brown, 1980; McKeown & Thomas, 2013; Watts & Stenner, 2012). We conducted a principal components analysis using varimax rotation. Inspection of the scree plot indicated a single factor accounted for a large portion of variance (34.06%). Thus, a single factor was extracted for analysis. Participants were segmented into three groups: one representing participants with positive loadings, one representing participants with negative loadings, and one representing participants that did not significantly load onto the factor (Brown, 1980).

To understand each segment's perspective, we constructed an 'average' Q sort (Brown, 1980). For each segment, the average ranking assigned to each statement by participants was calculated. This average was weighted by participants' loadings onto the factor, as a high loading indicates a participant's views closely align with that of the segment. The ordinal ranking of the weighted-averages of statements were used to reconstruct a Q-sort best representing that segment, known as factor scores (Table 2). The crib sheet approach (Watts & Stenner, 2012) was used to systematically compare factor scores for each segment. Factor scores were not calculated for the segment containing participants not loading significantly onto the factor as this segment is heterogeneous (if this group had homogeneous views, it would have emerged as another factor).

Overall, the factor extracted is a dimension of climate change acceptance, which was segmented into: (1) *Acceptors* whose positive load onto the factor is statistically significant ($n = 281$; 64.60%), (2) *Sceptics* whose negative load onto the factor is statistically significant ($n = 36$; 8.28%), and (3) *Opaque* whose loading onto the factor is not statistically significant ($n = 118$; 27.13%).[1]

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[1]Loadings with a magnitude greater than 0.36 are statistically significant at the $p < 0.05$ level for a 30 statement Q sort (Brown, 1980).

Table 2

Factor scores for each statement used in the Q sort.

Statement	Acceptor	Sceptic
1. It is important to vote for leaders who will combat climate change.	4	-4
2. Climate change is a hoax perpetrated by the United Nations.	-4	3
3. Scientists should stop falsely claiming that climate change is a settled science.	-2	4
4. Climate change is a threat to the health and safety of our children.	3	-3
5. They changed the name from "global warming" to "climate change" because the planet isn't warming.	-2	3
6. The concept of global warming was created by and for the Chinese in order to make U.S. manufacturing non-competitive.	-3	2
7. The Great Barrier Reef is at risk from climate change.	3	-2
8. The threat of climate change is much worse than climate scientists originally thought.	2	-3
9. Australian agriculture is thriving so climate change can't be real.	-3	2
10. The increased occurrence of extreme weather events is a clear sign that climate change is real.	2	-2
11. Australia is experiencing more extreme weather and hotter days due to climate change.	2	-2
12. Those who demand climate action are the usual "torch-and-pitchfork" crowd.	-2	2

Table 2

Factor scores for each statement used in the Q sort. (continued)

Statement	Acceptor	Sceptic
13. Cow farts cause more 'climate change' than human activity.	-2	1
14. Through cutting science funding, we damage Australia's ability to respond to climate change.	1	-2
15. Climate change policy and renewable energy (e.g., solar power) should be a major focus of Australian political elections.	2	-1
16. Oil and gas companies could not care less about climate change.	-1	2
17. Climate change sceptics ignore basic climate science facts.	1	-1
18. Politicians who refuse to tackle climate change are just as bad as those who deny climate science.	1	-1
19. No political party can say they have a climate change action plan when they favour coal, oil, and gas companies.	-1	1
20. Countries must fulfil their Paris Climate Agreement goals.	-1	1
21. Poor people will be impacted the worst by climate change.	1	0
22. Politicians and the mass media are ignorant about the risks of climate change.	0	-1
23. People who deny the science of climate change should not hold public office.	0	-1

Table 2

Factor scores for each statement used in the Q sort. (continued)

Statement	Acceptor	Sceptic
24. It is shameful that climate change, the greatest problem of our time, is barely discussed in the media.	-1	0
25. Regardless of who is elected, the reality is that climate change is going to destroy everything.	-1	0
26. Australian politicians need to wake up to the emergency of tackling climate change.	0	1
27. We must start working together for real solutions on climate change.	1	1
28. Climate change and human burning of fossil fuels are strongly linked.	0	0
29. We need to keep coal, oil, and gas in the ground and adopt more renewable energy sources, like solar and wind power.	0	0
30. Climate sceptics, with no genuine expertise, cannot know better than climate scientists.	*0*	*0*

Note: The difference between Acceptors and Sceptics in the weighted-averages of italicised statements are not statistically significant.

The Acceptors. Acceptors believe anthropogenic climate change is occurring (*statements* : 3, 10, 11, 13, 28), as indicated by an increased frequency of extreme weather and hotter days (*statements* : 5, 10, 11). Acceptors reject the notion climate change is a hoax (*statements* : 2, 6). Climate change is a climate process that will cause widespread changes: physical changes in weather (*statements* : 9, 10, 11); biological changes to ecosystems, such as damage to the Great Barrier Reef (*statements* : 4); and changes to human systems, threatening agriculture (*statements* : 6), future generations (*statements* : 4), and to a lesser degree, the poor (*statements* : 21). These climate

change impacts are worse than scientists initially thought ($statements: 8$), though there are still opportunities to mitigate and adapt ($statements: 12, 15, 25, 26$). Although action partly rests on collective society ($statements: 27$), it is leaders who must take charge ($statements: 1, 25$). In the words of Acceptors: "there are too many weak and idiot politicians in parliament. we need to vote in people who will take action" ($loading = 0.89$),[2] otherwise "climate change will spiral out of control" ($loading = 0.89$).

The Sceptics. Sceptics reject the concept of anthropogenic climate change ($statements: 3, 10, 11, 13, 28$). According to this segment, there is conclusive evidence human activities do not influence climate. Scientists who claim to have evidence rely on "dodgy modelling" ($loading = 0.86$) and "bullshit thought up by some brain dead idiots in university" ($loading = 0.71$). Thus, climate scientists have overestimated the frequency and intensity of current extreme weather events ($statements: 10, 11$), and will be incorrect in their projections for the future ($statements: 4, 7, 8$). Consequently, scientists changed the name of their area of study from "global warming" to "climate change", as the world is not warming ($statements: 5$).

As anthropogenic climate change "has nothing to do with science and reality" ($loading = 0.78$), Sceptics question the motives of institutions that endorse mitigative action ($statements: 2, 5$). For example, one participant claims "the United Nations is hiding behind climate change to acquire money" ($loading = 0.74$). Similarly, Sceptics argue against voting for leaders who will combat climate change ($statements: 1$) who are only concerned "about what they can get" ($loading = 0.68$). These leaders are "going to bankrupt Australia" ($loading = 0.74$) by "chasing ghosts" ($loading = 0.71$) as there is no way to "tame mother nature, money can't" ($loading = 0.56$). Citizens who demand solutions for climate change are the usual 'torch-and-pitchfork' crowd ($statements: 12$).

Predictors of segment membership. Segments differed in their responses on the psychological construct measures (Table 3). We constructed a regression model

[2]The loading of the participant indicates the degree to which the participant's Q sort matches the archetypal segment Q sort.

that predicts segment membership as a function of the different psychological constructs. To cope with multicollineraity (see Figure 2), we built a multinomial logistic ridge regression model. A ridge regression penalises the estimates of highly-correlated terms to achieve greater estimate reliability (a bias-variance tradeoff). For each level of the shrinkage parameter λ, different coefficients are estimated. A k-folds cross-validation process was used to determine the ideal value for λ. To calculate confidence intervals for coefficient weights, we used a bootstrap procedure (Efron & Tibshirani, 1994). One thousand samples were created by sampling participants (with replacement) from the study data. For each sample, the ridge regression and cross-validation processes were used to estimate coefficient weights. From the distributions of each coefficient weights, 95% confidence intervals were constructed.

Table 3

Means (and standard deviations) for the data overall and for each segment.

Scale	Overall	Acceptor	Opaque	Sceptic
BFI_A	3.62 (0.84)	3.67 (0.83)	3.56 (0.82)	3.43 (0.99)
BFI_C	3.76 (0.89)	3.77 (0.85)	3.64 (0.98)	4.07 (0.79)
BFI_E	2.85 (0.96)	2.85 (0.99)	2.88 (0.93)	2.79 (0.88)
BFI_N	2.77 (1.06)	2.89 (1.07)	2.64 (0.99)	2.26 (0.96)
BFI_O	3.32 (0.84)	3.36 (0.89)	3.24 (0.69)	3.31 (0.86)
CFC_F	3.74 (0.68)	3.88 (0.60)	3.58 (0.71)	3.22 (0.80)
CFC_I	2.57 (0.91)	2.36 (0.85)	2.95 (0.92)	2.95 (0.78)
CI	2.32 (1.02)	2.22 (0.95)	2.60 (1.11)	2.20 (1.07)
EWS_D	3.76 (0.75)	4.04 (0.56)	3.40 (0.71)	2.77 (0.84)
EWS_E	2.44 (0.92)	2.06 (0.69)	3.00 (0.83)	3.58 (0.94)
KV	2.69 (0.76)	2.73 (0.71)	2.57 (0.81)	2.78 (0.93)
MMS_CAU_C	5.06 (1.33)	5.56 (0.84)	4.59 (1.27)	2.69 (1.51)
MMS_CAU_E	4.61 (1.49)	5.00 (1.22)	4.33 (1.45)	2.42 (1.46)
MMS_CAU_N	4.23 (1.51)	4.15 (1.41)	4.49 (1.54)	3.99 (2.01)
MMS_CON_P	4.59 (1.58)	5.11 (1.28)	4.06 (1.56)	2.35 (1.19)
MMS_CON_S	5.12 (1.51)	5.73 (1.00)	4.40 (1.48)	2.68 (1.43)
MMS_HUM	5.59 (1.72)	6.31 (0.96)	4.93 (1.68)	2.14 (1.36)
MMS_MIT_C	4.19 (1.26)	4.33 (1.30)	3.89 (1.26)	4.06 (0.75)
MMS_MIT_E	4.04 (1.06)	4.03 (1.04)	3.98 (1.19)	4.25 (0.72)
MMS_MIT_G	4.69 (1.52)	4.91 (1.55)	4.27 (1.52)	4.40 (0.81)
NCS	3.36 (0.78)	3.36 (0.77)	3.33 (0.78)	3.45 (0.91)
PI	3.62 (1.59)	3.11 (1.45)	4.38 (1.36)	5.17 (1.34)
SJ	5.00 (1.58)	4.80 (1.48)	5.49 (1.48)	4.99 (2.24)
SS_E	2.97 (1.00)	2.51 (0.80)	3.60 (0.74)	4.42 (0.46)
SS_R	2.37 (1.01)	1.90 (0.73)	3.04 (0.87)	3.84 (0.54)

Table 3

Means (and standard deviations) for the data overall and for each segment. (continued)

Scale	Overall	Acceptor	Opaque	Sceptic
SVSS_C	1.43 (0.91)	1.26 (0.93)	1.67 (0.67)	2.05 (0.95)
SVSS_ST	-0.48 (0.97)	-0.40 (0.95)	-0.74 (0.99)	-0.31 (0.93)
W	2.72 (1.01)	3.10 (0.82)	2.30 (0.94)	1.17 (0.38)

Note: See Table 1 for meaning of construct abbreviations.

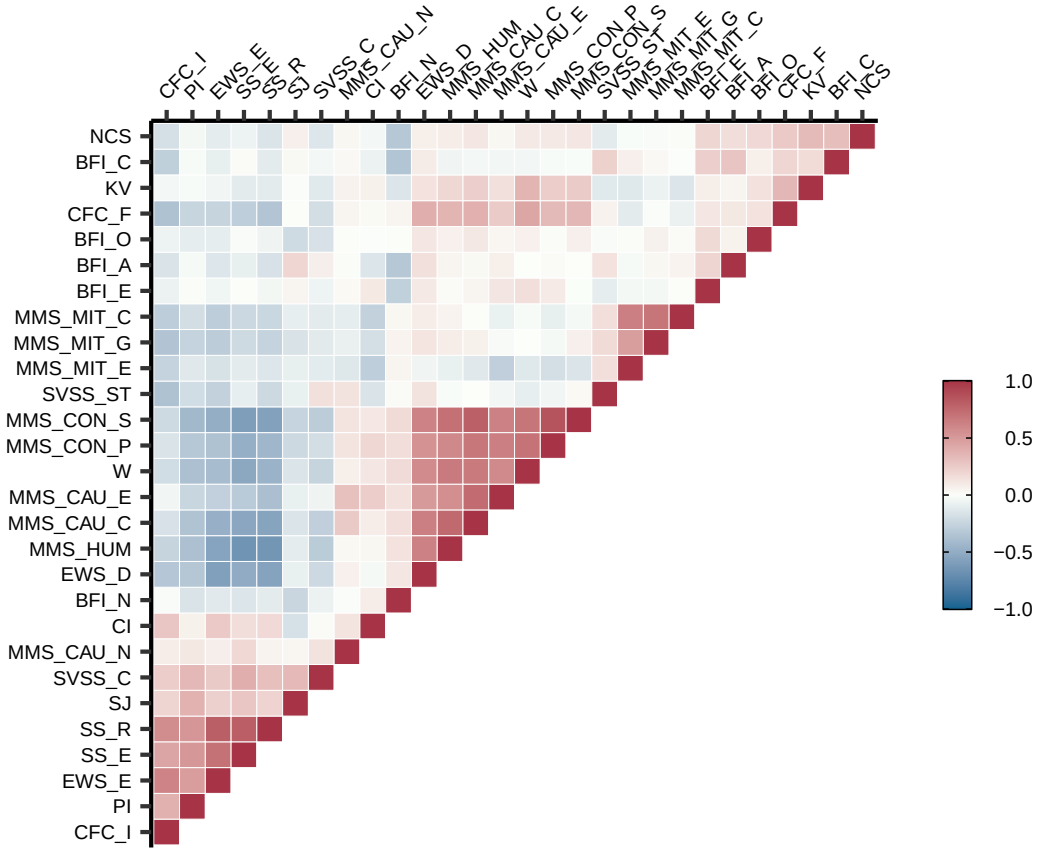


Figure 2. Pearson correlations of psychological constructs. See Table 1 for meaning of construct abbreviations.

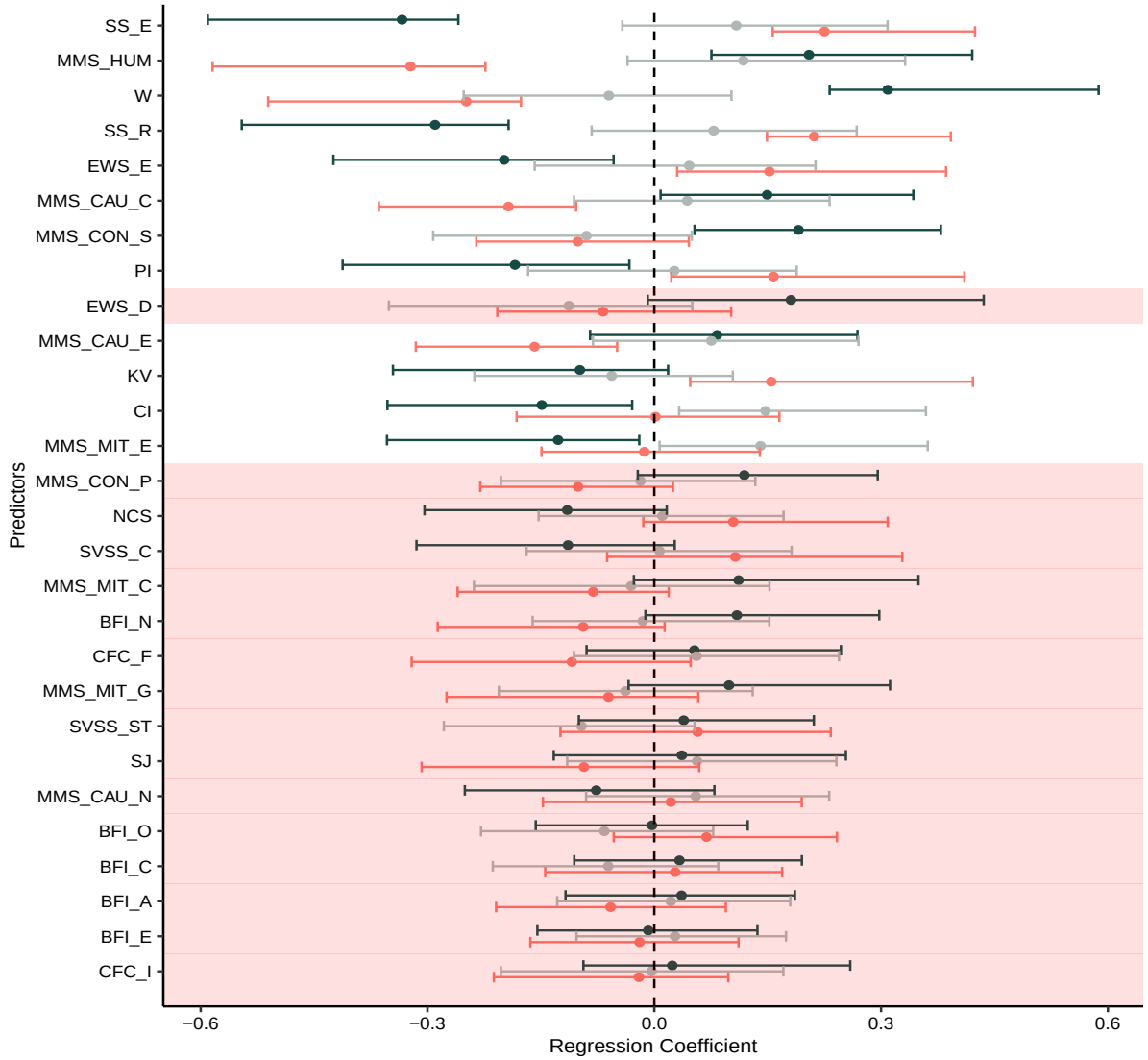


Figure 3. Regression weights for each variable used to predict segment membership. The weights (dot) and 95% confidence intervals (error bars) are presented for Acceptors (green), Opaque (grey), and Sceptics (pink). The weights apply to the z-score of the predictor variable. The pink background highlights predictors for which the confidence intervals contain zero for each segment coefficient. See Table 1 for meaning of predictor abbreviations.

Study 2

Study 1 provided evidence for three audience segments that differ in terms of psychological characteristics that transcend climate change (political ideology, environmental worldviews, and conspiratorial ideation) and specific climate change

beliefs that may be more easily refuted, such as those produced by mental models. Moreover, mental models, political ideology, and environmental worldviews were associated, suggesting some mental model components may be resistant to revision because of motivated reasoning (Kahan, 2013; Kahan et al., 2013). These results suggest the segments may differ in terms of their receptivity to climate science information.

To test this idea, in Study 2 we examined whether revision of mental model beliefs differed as a function of segment membership. We used a *belief-updating paradigm* where participants first provided numerical estimates for a set of climate change drivers or outcomes. Next, they were shown the corresponding scientific estimates, and asked to provide another set of estimates. The dependent measure of interest was the direction and degree of belief updating following receipt of the scientific estimates. We assessed updating across three mental model domains: climate change causes, climate change consequences, and effective mitigation of climate change.

Additionally, we explored two cognitive mechanisms which may account for the relationship between segment membership and belief revision. The first is trust in the source of incoming information. Acceptors are more likely to update towards climate scientific information than Sceptics, given the differences in political ideology, environmental worldviews, and scepticism of the two segments (Cook & Lewandowsky, 2016; Sunstein et al., 2017). The second mechanism is the optimism bias. This is the tendency for individuals to revise their beliefs to a greater degree when receiving good news (e.g., initially overestimating an event perceived as bad) than when receiving bad news (e.g., initially overestimating an event perceived as good; Garrett & Sharot, 2017; Ma et al., 2016). However, Sunstein et al. (2017) showed the optimism bias differs according to segment membership—when revising future-warming estimates, Sceptics updated optimistically, whereas Acceptors updated pessimistically. Accordingly, we explored the possibility segment differences in belief-updating can be explained by an optimism bias.

Finally, Study 2 was an opportunity to replicate the three-segment solution from Study 1. However, the addition of the belief-updating paradigm meant it was not

practical to include the psychological construct measures from Study 1.

Method

Participants. Qualtrics was used to recruit Australian adults ($N = 413$) using the same targeted and stratified sampling process focussed on age ($M = 46.82$, $SD = 18.04$) and gender (female = 47.94%). Along these characteristics, the sample was representative of the Australian population.

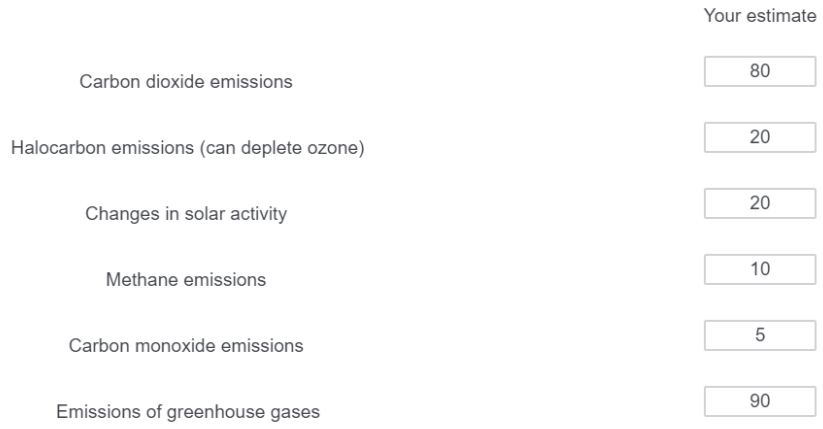
Materials and Procedure. All materials were presented to participants on a computer screen via a web browser. After providing informed consent and demographic data, participants completed the Q sort task used in Study 1. Following this, participants completed the trust inventory, belief-updating tasks (administred in a counterbalanced order, see Suplementary Materials), and sentiment inventory.

Trust inventory. Participants were informed they would be shown information from two sources: the peer-reviewed climate science literature and Climate Action Tracker.[3] For each source, participants read a lay description and indicated their trust of the source on a seven-point Likert scale, ranging from "strongly distrust" (1) to "strongly trust" (7).

Belief-updating tasks. We tested belief updating across three domains with five belief-updating tasks: (1) belief in causes of climate change (three tasks); (2) belief in consequences of climate change (one task); and (3) belief in effectiveness of mitigative policies (one task). Each belief-updating task contained two parts (see Figure 4). In part one, participants provided estimates for climate change drivers or outcomes (see Supplementary Materials for the specific belief items used), by entering values from 0 to 100 into text boxes. In part two, participants were shown the estimates they entered in part one alongside the estimates according to a relevant and specified scientific authority (climate scientists or Climate Action Tracker). Participants then provided a new estimate. The presentation of belief-updating tasks was counterbalanced across

[3]Climate Action Tracker conducts scientific analysis that tracks government commitments to climate action and assesses whether countries are on track to meeting those.

(a)



(b)

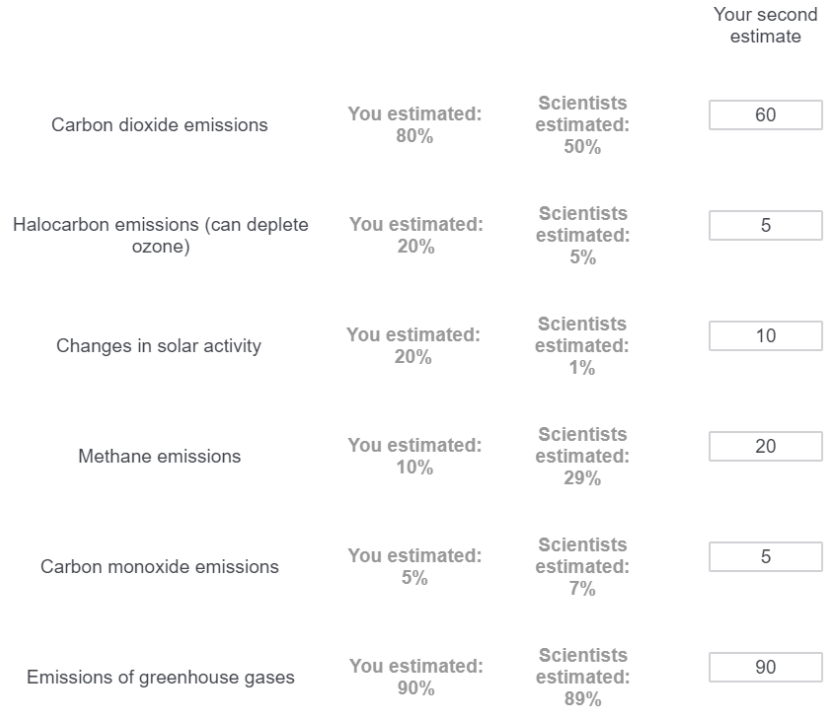


Figure 4. A belief-updating task for causal beliefs. In part one (a), participants indicated the percentage of climate change caused by each driver, over the period 1750 to 2011 (using the text entry box). In part two (b), participants were presented with their estimates from part one along with the corresponding scientific estimates. Participants then provided another estimate for each driver.

participants (see Supplementary Materials).

The first three belief-updating tasks concerned causal beliefs. For the first task, participants estimated the percentage of human-driven and nature-driven causes of climate change between 1980–2011. For this task, there were two beliefs: human-driven climate change and nature-driven climate change. For the second task, participants estimated the percentage of climate change caused by each of six mechanisms (e.g., "carbon dioxide emissions" and "changes in solar activity") between 1750–2011. For the third task, participants estimated the percentage of warming caused by greenhouse gas emissions from six human activities (e.g., "electricity use in residential buildings"). Before supplying their estimates, participants were informed greenhouse gas emissions drive most climate change.

Another belief-updating task concerned consequence beliefs. Participants estimated the degree to which nine climate events (e.g., "the number of hot days globally between 1901–2005") occurred because of anthropogenic climate change.

The final belief-updating task concerned mitigation beliefs. Participants were given information about the Paris Agreement and the Emissions Reduction Fund (hereafter 'ERF'), Australia's central climate policy. Then, participants estimated the change in Australia's carbon dioxide emissions by the year 2030 (compared to 2005 levels) under Australia's current climate policies. Unlike other tasks, participants indicated the direction of change of emissionsby using a drop-down menu (options: increase, decrease, no change) and the amount of change by entering a percentage.[4] Within both part one and two, participants indicated their approval of the ERF on a seven-point Likert scale, ranging from "strongly disagree" (1) to "strongly agree" (7); their level of approval of Australia's climate policies on the same seven-point Likert scale; and the likelihood Australia will meet the Paris Agreement (as a percentage, from 0 to 100).

Sentiment inventory. Participants indicated their feelings towards each climate change event presented in the belief-updating tasks, on a five-point Likert scale,

[4]Participants who indicated there would be no change in emissions had to enter "0".

ranging from "very negative" (1) to "very positive" (5). On the same scale, participants were asked "If Australia met its commitment to the Paris Agreement, how positive or negative would you feel about that?"

Results and Discussion

Segmentation solution. We identified a near-identical segmentation solution as in Study 1 (see Supplementary Material for factor scores). Of the sample, 256 participants were Acceptors 256 participants were Acceptors (61.99%), 114 were Opaque (27.60%), and 43 were Sceptics (10.41%).

Belief updating. The dependent variable of interest is *relative update*. This indicates the degree to which a participant revises their estimate following exposure to scientific information, as a proportion of their initial error. Separate relative belief update scores were calculated for each participant and for each belief item. The magnitude of an update score is the difference between the part one estimate and part two estimate, divided by the magnitude of difference between the part one estimate and the scientific estimate. The sign of the update score conveys whether the update was towards (positive) or away (negative) from the scientific estimate provided in part two.[5] Thus, a relative update of one indicates a revision to match the scientific estimate.

Linear mixed-effects modelling was used to determine whether relative update differed as a function of predictors (e.g., segment and trust). Each domain of belief (cause, consequence, and mitigation) was modelled separately. The general strategy involved the fitting of a baseline model containing an intercept. Where possible, this intercept was adjusted for each participant, for each belief item, and for each order of task administration. Conceptually, the baseline model represents the expected belief update adjusted for the variability of each participant, each belief item, and each order of task administration. Other models were then fit, each of which incorporated the same effects as the baseline model, alongside linear effects of different predictors on the

[5]For instances when the part one estimate equals the scientific estimate, a non-zero updates was coded as negative and a zero update was excluded from analysis.

update score. The Akaike information criterion (AIC) was used to assess the relative support for each model, where lower values indicate higher support.

For each model, both an AIC and ΔAIC was computed, where ΔAIC is the difference between the AIC of the given model and the minimum AIC of all models. The ΔAIC of the baseline model indicates the plausability that no predictors influenced belief updating. Models with $\Delta\text{AIC} \leq 2$ have substantial support; $4 \leq \Delta\text{AIC} \leq 7$ have considerably less support; and $\Delta\text{AIC} \geq 10$ have essentially no support (Burnham & Anderson, 2004).

Each mixed-effects model was fit using a log-likelihood criterion. The Wald method for estimating confidence intervals (CI) was used to determine which model coefficients differed from zero (at the 95% level). Sum contrasts were used to identify differences between levels of main effects in models with no interaction. One participant was excluded from analysis, as their data prevented model convergence. This participant provided a relative belief update several magnitudes higher than other participants.

For all domains, the fit of intercept-only models improved when including segment as a predictor. Thus, belief update varied across segments (Figure 5). Models with a main effect of segment and an intercept had a better fit than an intercept-only model. This indicates individuals of different segments differ in their relative belief update (Figure 5). For cause beliefs, Acceptors updated more than the Opaque (difference = 0.25, $CI = [0.12, 0.38]$), and the Opaque updated more than Sceptics (difference = 0.39, $CI = [0.19, 0.59]$). For consequence beliefs, Acceptors again updated more than the Opaque (difference = 0.25, $CI = [0.15, 0.34]$), who again updated more than Sceptics (difference = 0.24, $CI = [0.09, 0.40]$). For mitigation beliefs, the Opaque updated the most, although they did not statistically differ from Acceptors (difference = 0.07, $CI = [-0.20, 0.34]$). However, Acceptors updated more than Sceptics (difference = 0.53, $CI = [0.13, 0.92]$).

Segments may differ in belief updating solely due to differences in trust in informational source. However, this is not well-supported by the evidence. For all domains, models with only a main effect of segment were considerably more supported

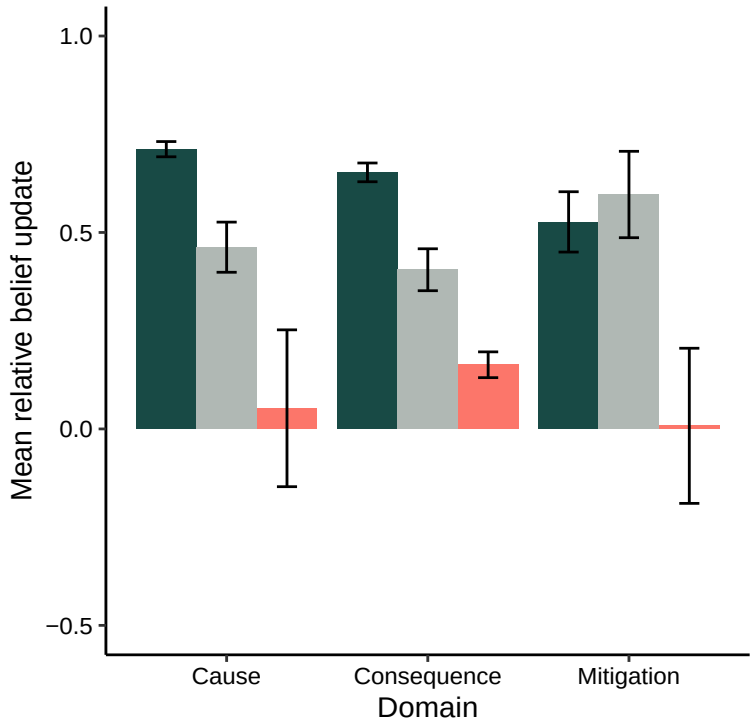


Figure 5. Mean relative update scores for each domain and segment: Acceptor (green), Opaque (grey), and Sceptic (pink). Error bars represent one between-participants standard error of the mean.

than models with only a main effect of trust (minimum $\Delta\text{AIC} = 4.35$). Thus, trust alone cannot account for the effect of segment on belief update.

Generally, the best fitting models for update of cause and consequence beliefs were those including effects for both trust and segment membership. Additionally, there were substantial support for interactions. For cause beliefs, greater trust was associated with greater update for Acceptors (0.09 more update per point of trust, $CI = [0.01, 0.16]$) and Sceptics (0.18 more update per point of trust, $CI = [0.08, 0.28]$), but not for Opaque (0.02 less update per point of trust, $CI = [-0.06, 0.10]$). For consequence beliefs, greater trust was associated with greater update for Acceptors (0.10 more update per point of trust, $CI = [0.04, 0.16]$), but not for Sceptics (0.04 more update per point of trust, $CI = [-0.04, 0.12]$) or Opaque (0.04 more update per point of trust, $CI = [-0.02, 0.10]$). For mitigation beliefs, there was little support for an interaction.

Segment differences in updating may be due to differences in optimisic revisions. To explore this possibility, we determined which scientific messages were good news and bad news on the basis of participants' emotional appraisals of events and their first estimates. For example, if a participant indicated an event was negative and was exposed to a scientific estimate greater than their first estimate, the events is bad news; conversely, if this scientific estimate was instead less than a participant's first estimate, the event is good news. Combinations of effects for segment and news (coded as good or bad) were entered into mixed-effects models.[6]

For consequence and mitigation beliefs, the most supported models were those containing main effects for segment and news type, but no interactions. There was a tendency towards a pessimistic updating for all segments, such that updating is larger for bad news than good news (Figure 6). As the best supported models contained an effect for segment, segment differences in update could not be solely accounted for by differences in an optimism/pessimism bias.

Change in policy support. Additionally, we identify the predictors of changes in policy support. To do so, we determined the fit of mixed-effects models with combinations of main effects and interactions of: segment; change in perceived mitigation effectiveness (positively-signed when policy perceived to be more effective); and change in perceived likelihood of Australia satisfying the Paris Agreement (positively-signed change when the Paris Agreement is perceived to be more likely to be satisfied).

For both support in the ERF and support in Australia's policy, two models had considerable support. The first model contained a main effect of segment, a main effect of perceived likelihood that Australia will satisfy Paris Agreement commitment, and an interaction between these two variables. The second model contains the same effects as the first, with an additional main effect of change in perceived mitigation effectiveness. For these models, the coefficient for the interaction between segment and perceived

[6]Update of neutral beliefs were not analysed. This included 1420 of 3708 consequence belief updates (38.30%) and 90 of 412 mitigation belief updates (21.84%).

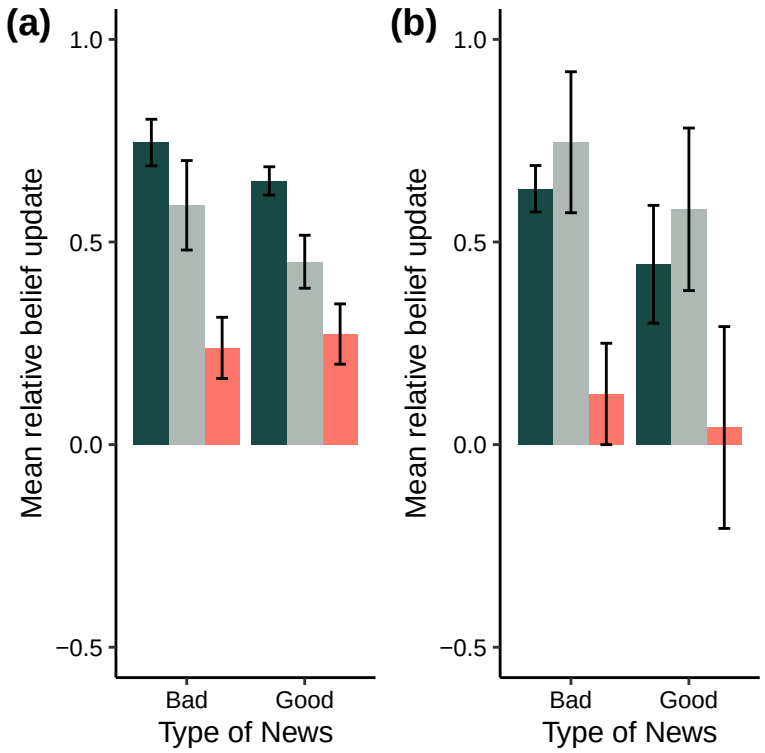


Figure 6. Mean relative update score for (a) consequence beliefs and (b) mitigation belief, as a function of news and segment: Acceptor (green), Opaque (grey), and Sceptic (pink). Error bars represent one between-participants standard error of the mean.

likelihood of meeting the Paris Agreement was only reliability signed (positive) for Acceptors (that is, the confidence interval did not intersect zero). Additionally, participants who updated towards greater perceived effectiveness of the ERF increased their support for the ERF (0.00378 change on the scale per 1% increment of carbon dioxide reduction, $CI = [0.00065, 0.00692]$), and their support for Australia's mitigation policies, although not reliably (0.00185 change on the scale per 1% increment of carbon dioxide reduction, $CI = [-0.00172, 0.00542]$).

General Discussion

We used a novel bottom-up approach to segment climate change views. Across two studies, we find consistent evidence for three distinct audience segments: Acceptors, Opaque, and Sceptics. In Study 1, we combined our bottom-up approach to segmentation based on the Q sort with a top-down approach to segment interpretation

by incorporating auxiliary measures of potentially relevant psychological constructs. Importantly, these auxiliary measures were used to help interpret the segments once they had been derived—they did not contribute to the segmentation process itself. This confluence of approaches revealed the three segments differ in their mental models of climate change and other psychological characteristics. Study 2 demonstrated segments differ in their belief-updating tendencies when exposed to scientific information. Overall, our studies indicate the Australian public are divisible into three audience segments with unique psychological characteristics and belief-updating tendencies. In the remainder of this discussion, we summarise the characteristic differences between segments, how these can inform communication strategies, and how our segmentation solution differs from previous research.

Characteristic differences between segments

Differences between segments can be understood by recourse to their sorting behaviour in the Q sort task, responses on the psychological construct measures, and updating tendencies in the belief-updating paradigm. From the Q sorts, it is apparent Acceptors strongly believe in the urgency and reality of climate change. They recognise climate change will have wide ranging impacts on the environment and society, and these impacts may be worse than climate scientists expect. They reject conspiratorial notions of climate change as a hoax, and they want to see political leadership and climate action. By contrast, Sceptics have an alternative perception of reality—one where the science suggests human actions are not influencing climate. Instead, climate change is a hoax manufactured to serve a hidden agenda. Accordingly, climate scientists are thought to use questionable research practices to create the illusion climate change is occurring. They think climate scientists' forecasts of global warming have been proved wrong and that, because of this, they deliberately changed the name of their field of study from "global warming" to "climate change". It is clear there is a distinctly conspiratorial flavour to the climate change perceptions of this segment. We cannot say anything specific about the Opaque other than that their sorting responses are more

heterogeneous than the other two segments. If there was a specific pattern to their sorting behaviour, then it would have emerged as a second factor in our statistical analysis.

Turning to auxiliary psychological construct measures, Acceptors strongly believe climate change is occurring and that carbon-emitting human activities cause climatic changes. They are more worried about the issue than the segments and strongly support climate action. This segment is politically liberal with an environment-as-ductile worldview, meaning they think the natural environment has a limited capacity to recover from damage. By contrast, Sceptics are less likely to believe climate change is occurring and that carbon-emitting human activities cause climatic changes; yet, Sceptics have the greatest self-confidence in their knowledge about climate change. They are therefore sceptical of the need for climate action. This segment is politically conservative with an environment-as-elastic worldview, meaning they think the environment easily recovers from damage. Surprisingly, Sceptics did not show higher levels of dispositional conspiratorial ideation, despite their strong endorsement of climate-conspiracy related items in the Q sort. However, Opaque showed higher levels of dispositional conspiratorial ideation than Acceptors and Sceptics. The only other characteristic that distinguished Opaque was their relatively high belief in the efficacy of engineering solutions to climate change.

That dispositional conspiratorial ideation was elevated in the Opaque, but not Sceptics, seemingly contradicts an extensive literature showing conspiratorial ideation predicts climate change scepticism (Hornsey et al., 2018; Kaiser & Puschmann, 2017; Lewandowsky et al., 2013). However, Lewandowsky (2020) recently suggested individuals may deploy conspiratorial explanations for two different reasons: (1) they have a general disposition towards engaging in conspiratorial ideation; and/or (2) they seek to guard against worldview-incongruent information. In the latter case, conspiracy theories may not reflect people's real attitudes to climate change but may instead be a pragmatic tool to indicate a person's political stance on the issue. Consistent with this characterisation, Opaque showed greater general disposition toward conspiracism in the

absence of a specific tendency toward climate change conspiracy theorising, and they are moderate in terms of their political ideology and worldviews. By comparison, Sceptics do not show an increased general disposition toward conspiracism, but they do show a specific tendency toward climate change conspiracy theorising, accompanied by politically conservative ideology and environment-as-elastic worldviews. Thus, Opaque and Sceptics may differ in their use of conspiratorial explanations for climate change.

Finally, the segments differed in terms of the degree to which they revised their beliefs vis-á-vis scientific information. Specifically, for climate change causes and consequences Acceptors updated their beliefs more than Opaque, who in turn updated their beliefs more than Sceptics. For mitigation, Acceptors and Opaque revised their beliefs to a comparable degree, and more so than Sceptics. The effects of segment on belief updating could not be fully accounted for by trust in information source or an optimism bias. In general, Acceptors and Opaque showed a high degree of willingness to revise their beliefs, whereas Sceptics were highly resistant to revising their beliefs. The willingness of Opaque but not Sceptics to update their beliefs in response to scientific information confers further support for the notion that the two segments may deploy conspiracy theories for different reasons.

Communicating with the different segments

To bolster public support for mitigative policies, communicators should focus on the Opaque. Acceptors already trust climate science and support strong leadership to address climate change, whereas Sceptics are politically-motivated to oppose mitigative policy, and are thereby resistant to belief updating. In contrast, the Opaque show potential for belief change, as they update their beliefs in response to scientific findings and are not characterised by extreme environmental worldviews or political ideology. However, this is a double-edged sword. Just as Opaque could be tipped towards greater climate change acceptance by exposure to scientific information, they could be tipped toward scepticism by exposure to disinformation.

To protect the Opaque from climate change disinformation, communicators

should preemptively use inoculation techniques to build psychological resistance to disinformation before it is perceived (McGuire & Papageorgis, 1961). Inoculation involves warning individuals they may be exposed to disinformation and explaining to them the deceptive strategies and rhetorical techniques used by those that seek to mislead (van der Linden et al., 2017). For example, Cook et al. (2017) found climate change disinformation could be successfully inoculated by altering individuals to the use of 'fake experts' by the fossil fuel industry. Such approaches are particularly promising for Opaque, as exposing the hidden agendas of industry leverages the segment's elevated conspiratorial disposition. Alternatively, if disinformation has already informed belief, communicators may use various best-practice debunking strategies to correct the disinformation (Lewandowsky et al., 2020; Lewandowsky et al., 2012; Lewandowsky et al., 2017).

Additionally, the Opaque are at risk of over-estimating the effectiveness of engineering solutions to climate change. Such optimism is potentially problematic, as believing that engineering can provide an 'easy technological fix' to the climate crisis may lead to questioning the need to cut emissions (Robock et al., 2008). Thus, communicators should use educational interventions to highlight scientific understanding of the potential role of different engineering solutions, the circumstances under which they might be deployed, and their potential risks and limitations. Simultaneously, communicators should provide education on the more effective carbon-limiting policies, as the effectiveness of these policies may be under-estimated by Opaque. Given Opaque do revise their beliefs in the face of scientific information, such education should be effective and worthwhile.

Although we emphasise the Opaque, public support for mitigation policy can be bolstered within Acceptors and potentially Sceptics. Despite worry about climate change and having knowledge on its causes, many Acceptors fail to distinguish between effective and ineffective policies. To reduce support for ineffective policies, communicators could encourage Acceptors to apply their causal knowledge of greenhouse gases to the policy domain. Alternatively, as demonstrated in the current

work, communicators could directly highlight the ineffectiveness of a policy and the adverse impacts on international agreements. In contrast, Opaque and Sceptics were not persuaded by the consequences of ineffective policy on international agreements. Messages from climate scientists could be persuasive, as climate scientists are trusted by Acceptors.

Of all segments, Sceptics were most resistant to belief revision when contradicted by science. Thus, communicators may need to deploy unique strategies to foster more positive attitudes towards climate science and policy in this segment. One approach is to leverage people's motivations to maintain cognitive consistency in attitudes. For example, Gehlbach et al. (2019) found conservatives asked to rate the generally accepted contributions of science to society, such as discovering germs cause disease, had more positive attitudes towards climate science than conservatives asked solely about their climate science attitudes. Alternatively, communicators may avoid climate science entirely by appealing to the benefits of mitigation policy to improve policy endorsement, such as communicating the moral or economic co-benefits (Bain et al., 2015).

Lastly, for all segments, we caution communicators from assuming changing belief in the causes or consequences of climate change will necessarily change beliefs of effective mitigation. Our findings suggest mental models of cause and consequence differ from those of mitigation. For example, we found mental models of causes and consequences are strongly associated, but both are weakly associated with mental models of mitigation. Corroborating this distinction, segment updating tendencies were similar for cause and consequence beliefs, but both were different from patterns of mitigation belief updating. Thus, improving scientific literacy of climate change causes and consequences does not guarantee changes in the perceived effectiveness of policy.

Comparison to previous segmentation research

We identified three segments, a number on the lower range of segments derived using top-down segmentation approaches (Hine et al., 2014). This discrepancy may be due to differences in the segmentation approach deployed. For example, the bottom-up

approach ensures segments are divided on their views of popular features of public climate change discourse that may shape and sustain their attitudes on the issue, rather than researcher-driven expectations about what content is relevant. A potential problem with top-down approaches is they may incorporate irrelevant variables that generate spurious distinctions between segments or use statistical techniques that lead to a superfluous proliferation of segments. Thus, a segment holding similar perceptions may be divided into two segments based on another variable, empirically unrelated to perceptions but thought by researchers to be theoretically related. One such auxiliary construct may be values, as we found values do not predict climate change perceptions when accounting for other psychological constructs. Accordingly, bottom-up approaches may potentially produce segments that are less redudant than top-down approaches.

Alternatively, the limited segments extracted may be result of political ideology constraining climate change views. Climate change is a politically polarised issue in some countries (Hornsey et al., 2018), such as the United States of America (Dunlap, 2019) and Australia (Essential Research, 2019). This polarisation is reflected in our segments, which are divided by their political affiliation, worry about climate change, and climate change scepticism. This dimension of worry and scepticism can be seen in other segmentation studies, such as the *Six Americas*. Although containing six segments, this research was conducted in 2008. Since then, American's have become increasingly politically polarised in their climate change views (Dunlap, 2019; Kennedy, 2020; McCright & Dunlap, 2011). Similarly, studies from the earlier part of 2010-2020 found three to six segments for Australians' climate change views (Ashworth et al., 2011; Hine et al., 2016; Morrison et al., 2013). Our current work cautiously suggests that for Australians, and perhaps Americans, climate change views have consolidated along political lines.

Lastly, our findings could be uniquely characteristic of our sample. For example, sampling Australians may prevent generalising our results to other countries. However, as aforementioned, our segmentation structure is reflected in studies of other nations. Our findings may particularly relevant to nations where climate change scepticism is

politically polarised, such as the United States, Canada, and Brazil (Hornsey et al., 2018).

Conclusion

The predominant approach to segmentation of climate change audiences is the top-down approach, which privileges researcher preconceptions over audience conceptions of climate change. In contrast, we used a bottom-up approach to ensure segmentation reflects lay views on climate change, as defined by the public. However, we did not disregard theory—we complimented our segmentation by examining the psychological characteristics of segments. We found the Australian public is composed of three segments—Acceptors, the Opaque, and Sceptics—with unique psychological characteristics and belief-revision tendencies. Communication can be enhanced, our results suggest, by conceptualising the public as homogeneous segments, rather than a homogeneous whole. Yet, many communicators rely on a 'one-size-fits-all' approach. For these communicators, our research outlines a comprehensive profile of segments along with recommendations for communicating with each. We suggest communicators should target the Opaque who hold moderate views and are receptive to belief revision. Care must nevertheless be taken since although the Opaque are receptive to scientific information they are also potentially vulnerable to misinformation and conspiratorial thinking.

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