Investigating single bound probability estimates, motivated reasoning, and motivated memory regarding information about climate change

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Abstract

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Scientists may utilise single bound probability estimates to convey the uncertainty around climate change. Such estimates employ a verbal moderating statement to describe the lower (e.g., more than 60% likely) and/or upper bound (e.g., less than 70% likely) of a probability. Previous research has shown that single bound statements can convey many pragmatic implications, such as information about the speaker and trends. The current thesis concentrated on how individuals evaluate and remember single bound probability estimates, with an additional focus on how individual differences affect memory and appraisal. These outcomes were investigated after a delay, since people do not often make decisions about climate change information immediately after reading it. Two studies were conducted with 101 and 92 subjects respectively. In both studies participants viewed two forecasts about climate change, which separately encompassed both an upper and lower bound probability estimate. Participants then recorded their beliefs about climate change and cultural cognition during a delay period, prior to evaluating the credibility of the forecast and completing a free-recall task. In the second study participants also completed a recognition task where they were instructed to identify the original single bound probability estimate from a series of distractors. In both studies, the forecasts were rated as more credible when utilising a "more than" statement compared to a "less than" statement. However, when recalling the estimates, very few participants remembered that there was a single bound statement used in conjunction with the probability. In the second study, hierarchical and individualistic climate sceptics viewed the forecasts as less credible than believers. The thesis was able to demonstrate the various factors that scientists should take into account when determining the best way to communicate the uncertainty around climate change. By integrating the knowledge about how single bound probability estimates are evaluated with a focus on motivated reasoning, researchers who use such statements can decide how best to frame them in order to enact behaviour change from climate change acceptors and sceptics alike.

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1 Introduction

Information about climate change, like many high impact risk forecasts, is inherently uncertain. An important role of climate scientists is to effectively communicate this uncertainty to policy makers and to the general public. They do this in a variety of ways, including the use of verbal expressions (e.g., "it is *very likely* the sea level will rise by 20 inches"), numerical ranges (e.g., "the sea level will rise by *10* to *30* inches"), probability statements (e.g., it is *90% likely* that the sea level will rise by 20 inches), or an amalgamation of both verbal and numerical terms.

The method by which experts communicate uncertainty can determine how well they are understood, and whether the information they disseminate will lead to new environmental policy or change in public attitudes and behaviours. Several criteria exist for determining which method of communication is most appropriate, including, but not limited to, how well the audience comprehends the expression, how salient and useful the information is, and whether it leads to motivated evaluation (Dieckmann, Gregory, Peters, & Hartman, 2017).

Verbal expressions (e.g., unlikely, likely, very likely) are easy to use, they are consistent with a vast range of numerical probabilities, and because of their vague nature they may be able to convey the level of uncertainty that exists within the field of climate science (Budescu, Broomell, & Por, 2009; Lipkus, 2007). However, the vagueness of verbal expressions is also one of their major weaknesses. The ambiguity of such statements means that people are often uncertain how to interpret them, leading to miscommunication and a lack of understanding. Budescu et al. (2009) found that individuals associate verbal expressions with wide probability ranges that are often inaccurate. The Intergovernmental Panel on Climate Change intends the phrase "very likely" to mean probabilities of 90% to 99% (Mastrandrea et al., 2010), however in Budescu and colleagues (2009) study, 58% of participants gave inconsistent translations of this phrase (and other phrases) despite having access to a table that converted the expression into the correct probability range.

Numeric methods of communication are thought to be more precise than verbal expressions and are said to result in more accurate perceptions of risk. However, they are not immune to problems: For example, issues with interpretation can arise when people lack the knowledge to understand the mathematical constructs (Lipkus, 2007). Specifically, numeric ranges have been shown to elicit motivated evaluation; the individual interpreting them will often choose quantities towards the upper and lower limits of the range that are most consistent with their ideology and pre-existing beliefs about climate change (Deickmann et

al., 2017). Concerning a numerical range that forecasts sea level rise for example, individuals who are sceptical of climate change may argue that quantities towards the lower end of the range are more likely to occur, whereas people who believe the climate is changing may navigate towards the higher numbers. Budescu, Por, and Broomell (2011) argue that using a combination of both verbal and numerical terms is most appropriate for communicating information about climate change.

One method of conveying uncertainty concerns so called "single bound probability estimates" (Hohle & Teigen, 2018). These statements describe either the lower bounds (more than, over, minimum) or upper bounds (less than, under, maximum) of a probability distribution. They utilise both a numerical probability and a verbal expression that acts as a moderator of the quantity, for example "more than 50%" or "a maximum of 30%". These estimates have received very little research attention in the area of climate change, yet they could be a suitable method for communicating the uncertainty within the field. Whereas other methods of communication have been researched widely, to my knowledge only one study has focussed on single bound probability estimates regarding information about climate change (Hohle & Teigen, 2018).

Furthermore, very few studies have assessed how people remember information about climate change after a delay. This has little application, as people do not often respond to or make decisions about climate change information directly after reading it. This is especially relevant to people who believe the threat of climate change to be distant both spatially and temporally (van der Linden, Maibach, & Leiserowitz, 2015). Individuals may instead assign weight to the information they read and store it alongside other facts until enough research from different sources acts as a catalyst to attitude change (Kahan, Jenkins-Smith, & Braman, 2011). In the current thesis, I aim to determine the efficacy of single bound estimates as a method of communicating climate change information. The thesis will also take the previous research a step further by analysing how such statements are evaluated and remembered after a delay by different groups of people, including climate sceptics.

1.1 Single bound statements

Single bound statements can be separated into inclusive (minimum, maximum) and exclusive (more than, less than) statements. Inclusive statements are seen to incorporate the highest or lowest numerical bound, for example "a minimum of 60%" can include values above 60% and 60% itself. Exclusive statements are generally evaluated as not including the

highest or lowest stated bound, for example "less than 50%" is thought to mean any probability below 50% but not 50% itself (Teigen, Halberg, & Fostervold, 2007).

Audiences are free to interpret a single bound probability estimate at any point along its range (e.g., an inclusive lower bound statement could be understood anywhere from its stated probability to 100%). However, studies have shown that people tend to anchor such estimates fairly close to the value reported (Harris, Por, & Broomell, 2017). For example, a probability of "over 50%" elicits an average estimate of 52.4%, and a probability of "under 50%" is estimated to mean 48.1% (Hohle & Teigen, 2018). It is worth noting here that upper bound and lower bound statements can be applied to quantities more generally, in addition to probabilities.

Single bound statements communicate not only numeric information, but also pragmatic implications. When engaging in conversation, understanding of the semantics alone is oftentimes insufficient for meaningful exchange; listeners must make pragmatic implications from what is said in order to comprehend the speakers intentions (Wänke, 2007). For example, Wänke (2007) notes the case of two women at a holiday resort, the first woman asks, "Where do you come from?", and the second replies "From my room". It is evident that the second woman comprehends the semantics but has not made the appropriate pragmatic inferences to understand that the first woman is asking which country she is from. This logic can also be applied to single bound statements. Grice (1975) suggests that it is specific words that determine what is implicated in a sentence; in single bound statements the verbal moderator can facilitate better pragmatic understanding of the quantity and the topic of conversation.

To illustrate, single bound statements can allow the reader to make inferences about the speaker. Individuals can be viewed as either pessimistic or optimistic based on whether they use upper or lower bounds; Teigen et al. (2007) found that if a speaker says his flat is worth a "minimum of one million" he is judged as being more optimistic and less pessimistic than a speaker who believes her flat is worth a "maximum of two million"; even though the second speaker expects to receive more money from selling her flat.

When single bound statements are applied to the cost of an item, they can imply a number of things, one being whether it is advisable to buy that item. Teigen et al. (2007) conducted a study where participants had to choose between upper and lower bound statements to either encourage or discourage a purchase; almost all participants who were told to discourage a purchase selected the lower bound (more than) statement to advise against buying it, despite it being coupled with a cheaper price (600 Norwegian krone compared to

900 Norwegian krone). The researchers hypothesised that values above a reference point (more than X) are indicative of a surplus, whereas values below a reference point (less than X) are suggestive of a deficit. In this case, the values above the reference point indicated a surplus of expense, despite the difference in numerical value. The fact that participants chose lower bound statements that were combined with a cheaper price to discourage the purchase, suggests that they were assigning more weight to the verbal expression, rather than the price of the items when making pragmatic implications.

Information about directionality (i.e., whether an event is seen as likely or unlikely to occur) can also be inferred from single bound probability statements (Teigen, 2008). Teigen and Brun (1995) identify two kinds of verbal probability terms, those which direct attention to the occurrence of an outcome (terms with *positive directionality*, e.g., a chance, likely, possible), and those that point to the events' non-occurrence (terms *with negative directionality*, e.g., not certain, unlikely). Lower bound statements, such as "more than 50%", may be seen as an instance of a positive directionality term, while upper bound statements, such as "less than 60%", can often be perceived as unlikely to occur due to their negative directionality.

Furthermore, individuals can extract information from single bound probability estimates that suggest whether the speaker, or communicator, expects the event to happen. Experts who posited that an event had an "over 50%" chance of occurring were judged by participants to expect the phenomenon to arise, whereas experts who argued "under 70%" were seen not expect the event to happen regardless of the high numerical probability (Hohle & Teigen, 2018). This suggests that the participants' attention was directed to the occurrence or non-occurrence of the event by the verbal part of the statement.

To the best of my knowledge, only one study has focussed on how people interpret single bound probability estimates specifically regarding climate change. Hohle and Teigen (2018) conducted research to investigate the pragmatic implications that people make from upper and lower bound statements. In one study, participants were given two climate change related scenarios concerning glacier reduction and increased sea levels, these were presented with either lower bound or upper bound probability estimates. Despite the probabilities being larger in the upper bound condition (under 50%, under 70%) compared to the lower bound condition (over 30%, over 50%), participants who received these estimates assigned negative phrases to them (e.g., "it is uncertain") and gave reasons for why the event would not occur. This finding supports the idea that participants' attention was directed by the verbal part of the statement rather that the numerical probability itself, since under 70%, for example, is still

quite a substantial probability estimate. “Over” statements were judged more compatible with positively directed phrases, and vice versa for “under” statements, even though the numerical probabilities were higher in the “under” condition.

Individuals can also make inferences about trends from single bound probability statements. Hohle & Teigen (2015) found that participants who were told that a climate scientist had become 10% more certain of a temperature rise believed that she would be even more certain in her next report; the opposite was true for the scenario in which the scientist became 10% less certain. In a later study the researchers found that trends can be inferred from a single observation depending upon the way it is framed. The directionality that is implied in a single bound statement indicates the possibility of a future upward or downward change (Hohle & Teigen, 2018): If an event is more than 60% probable now, it might become even more probable in the future, while if it is less than 60% likely, the chances of it occurring may actually go down.

The plethora of evidence shows that single bound statements lead the reader to suppose something about the topic that was not plainly stated in the text. Single bound probability estimates are more *evaluable* than probabilities more generally (Hsee, 1996). The meaning and value of probabilities alone is often difficult to assess without access to information such as the value distribution, and the best and worst possible quantities (Hohle & Teigen, 2018). Upper and lower bound statements modify the probability estimate to give it more value and evaluability. In other words, individuals can make more meaningful conclusions about the probability with the inclusion of a single bound statement.

Single bound statements convey a myriad of pragmatic implications, including inferences about the speaker, directionality, and information about trends. Furthermore, they communicate implications that are specific to the topic they describe, for example, when applied to price, single bound statements can help an individual decide whether a speaker recommends purchasing a particular item. In the present thesis I expect to find results that correspond to findings from researchers who demonstrate that pragmatic implications can be made from single bound probability estimates, with a specific focus on climate change. This thesis will extend previous research by investigating these effects after a delay to examine how individuals evaluate such statements when they are not as clear in mind.

1.1.1 How might people remember single bound probability estimates?

It is evident that single bound statements communicate a multitude of distinctive implications and inferences, and that they can be appraised and evaluated very differently

depending on whether they utilise an upper or lower bound. Since individuals do not often respond to climate change information immediately whilst reading it, this not only poses the question of how scenarios encompassing single bound probability estimates are evaluated after a delay, but also how they are remembered. It could be that the verbal, moderating part of the statement is more long-lasting in an individuals' mind than the probability itself, since it has been shown to receive the most weight and attention during evaluation (Hohle & Teigen, 2018).

Gilovich, Griffin, and Kahneman (2002) remark that information processing is limited therefore individuals may use fast and frugal approaches to reasoning. By their very nature, single bound statements convey the essence of what the speaker is saying, ergo they simplify the processing of probabilistic statements by demanding less knowledge of what the probability actually means, especially for those low in numeric ability. Hohle and Teigen (2018) remark that people may even find it easier to later recall the positive or negative tone of the message (the bottom-line meaning) rather than the specific numerical probabilities involved (verbatim information) which may have disappeared from memory.

Findings from previous research on risk communication suggest that people rely on "gist" interpretations, or the bottom-line meaning, as opposed to verbatim facts or figures when recalling information about risk (Reyna & Hamilton, 2001). To elaborate, verbatim memories represent the facts and details of information (e.g., explicit numbers) but, according to Reyna, they rapidly fade. Gist memories however, which reflect how the individual understands and interprets the statement, are more long-lasting. Reyna (2004) uses fuzzy trace theory to explain how risk information is represented, retrieved and processed (Reyna & Brainerd, 1995): Individuals are thought to use both verbatim memories (reproductive memory) and gist representations (reconstructive memory) to make decisions, however there is a primary reliance on gist since it is more easily encoded and retained. Reasoning that is based on gist processing is suggested to underlie superior cognition, hence it is with age and expertise that people tend to rely on the simplest gist necessary to complete a task, such as a memory test (Corbin, Reyna, Weldon, & Brainerd, 2015).

Support for this theory comes from researchers who investigated how patients recall risk information when consenting to heart surgery that had a two percent risk of death, to correct a problem that had a 22% risk of stroke (Lloyd, Hayes, Bell, & Naylor, 2001; Reyna & Hamilton, 2001). They found that although patients failed to remember the verbatim figures they were able to accurately order the classes of risks, offering support for the idea that gist information prevails, certainly over the short term.

Reyna and Mills (2014) found evidence that gist interpretations are also preserved in the long term. In order to reduce sexual risk taking among adolescents in three American states, the researchers compared the effects of an intervention called "Reducing the Risk" with a modified version of the intervention, adapted to included aspects of fuzzy trace theory. The two interventions shared all content regarding elimination and reduction of risk, however the modified version encouraged gist extraction (understanding of the bottom-line meaning) and application of values to gist representations. Despite communicating the same facts about risk, the modified intervention had a greater impact than the original by emphasising short summaries of crucial points at the end of each lesson, in order to facilitate long-term encoding of important information. By emphasising the gist representations, the enhanced intervention resulted in larger and more sustained effects at follow-up sessions after a six month and one-year period. This research supports the belief that gist interpretations are preserved over longer periods of time compared to verbatim facts, and that they become vital memories used in decision making.

The idea of verbatim and gist representations may explain why, in Hohle and Teigen's (2018) study, participants evaluated single bound probability estimates of "under 70%" as less likely to occur than statements of "over 50%". They did this despite believing that "under 70%" translated to a probability of 57%, and "over 50%" to 52.4%. Although there was no delay allowing verbatim information to fade from memory in this study, participants still used gist representations conveyed by the positive or negative directionality of the statements to process the essence of the risk information, focussing on the verbal gist and discounting the numerical verbatim. This highlights how speakers may be able to use lower bounds to inflate small chances and upper bounds to downplay large chances, enabling them to manipulate their listeners to think in a certain way.

Evidence illustrates that single bound statements are able to direct attention one way or the other (Hohle & Teigen, 2018). This idea, coupled with the evidence suggesting that the gist is the most salient part of risk information, may mean that individuals are influenced to remember numerical probabilities that are in line with the direction of the single bound statement.

Regarding research on false memories, Brainerd and Reyna (2002) note that incorrectly remembered information is often consistent with the gist of participants' experiences. Harris, Teske, and Ginns (1975) found that during a mock court case, people were affected by pragmatic implications, and remembered implied statements as being explicitly stated, even when they were warned to watch out for such statements. Applied to

single bound probability estimates, it could be construed that individuals will recall incorrect probabilities that are in line with the way that they evaluated them (i.e., the pragmatic implications that they made from the scenarios based on the directionality of the single bound). To clarify, using "more than" denotes a considerable chance of an event occurring, while the use of "less than", can be seen to mean that the probability is small (Hohle & Teigen, 2018). When recalling this information at a later time, it is plausible to suggest that people will remember quantities preceded by "more than" to be higher than the stated value, and probabilities preceded by "less than" to be lower, not only because of the exclusivity of such statements, but also because of their focus on the gist of the statement. For example, using upper bound (less than) statements may cause the individual to disregard the numeric probability and remember it as being lower than it was because the verbal moderator has influenced them to evaluate it as insignificant and unlikely to occur.

In the current study I aim to investigate how single bound probability estimates are evaluated and remembered after a delay, with a specific focus on gist and directional effects. Since evidence has shown that individuals overweight the verbal part of the statement when interpreting what the probability estimate means, it is possible that the gist is what remains most salient after a delay. Exploring how the gist and the directionality of single bound statements affect memory for facts about climate change, will not only shed light upon how such statements are remembered but also offer insight to experts on how best to frame and utilise single bound probability estimates in order to enact changed attitudes and subsequent "climate-friendly" behaviour from their audience.

1.2 Motivated reasoning and motivated memory

As many as 97% of climate scientists agree that climate change is rapidly occurring due to human behaviour (Cook et al., 2016). Natural scientists report that climate change will result in many negative consequences for our planet, including a rise in sea levels, more frequent droughts, and an increase in the number of natural disasters (Melillo, 2014). Despite the overwhelming consensus of the scientific community, only 48% of the American public support the view that anthropogenic climate change is occurring now (Funk & Kennedy, 2016). One fifth (20%) of the population surveyed argue that there is in fact no evidence for the occurrence of climate change whatsoever.

Scepticism of climate change can be seen most clearly amongst specific American groups; most notably conservative Republicans and those whose political views lean this way.

Research has found that only 15% of this particular group, compared to 79% of liberal Democrats, agree with the current scientific consensus (Pew Research Center, 2016). Additionally, and perhaps more interestingly, conservative Republicans are sceptical of climate scientists and their motives. Pew Research Center (2016) found that only 15% of conservative Republicans believe that scientists' research can be trusted, whilst 57% argue that climate scientists' research findings are influenced primarily by a desire to advance their careers.

Motivated reasoning may explain why such individuals reject the scientific consensus in favour of climate scepticism. The phenomenon refers to the tendency of people to make decisions about given information that conform to some kind of end goal (Kunda, 1990). Often this concerns conserving one's own perceived identity and social standing within a like-minded group that shares central values (Kahan, 2013). Individuals often gain emotional and material support from these affinity groups, so it stands that they are motivated (consciously or unconsciously) to resist evidence that would threaten one's group membership if it were opposing the dominant belief within the collective (Cohen, Bastardi, Sherman, Hsu, McGoey, & Ross, 2007). This type of motivated reasoning may be observed amongst the 85% of conservative Republicans who do not believe that anthropogenic climate change is occurring currently (Pew Research Center, 2016). The party policies that many of these people support may contrast with the current scientific consensus, potentially leading these individuals to reject empirical evidence in order to sustain affinity within their political group (Kahan, 2013).

More generally, people are motivated to construe information in a way that is self-serving and promotes their personal values and ideologies (Kahan, 2013). Heath and Gifford (2006) established that support for the free market system correlates with scepticism of anthropogenic climate change and disbelief that it will result in negative consequences. Values and beliefs that accompany capitalism are suggested to be inconsistent with environmental preservation (Axelrod & Suedfeld, 1995), ergo the individual who subscribes to free market ideology is likely to reject the myriad of evidence on climate change in order to protect his or her values.

Motivated reasoning has been shown to lead to motivated memory, whereby individuals misremember facts in alignment with their beliefs. For example, previous research has found that motivated reasoning leads to distorted views about past weather events. Weber (1997) asked a sample of American soya bean and corn farmers to graph the amount of rainfall experienced between April and July over the previous seven years. Farmers who

believed that the climate was changing displayed distorted memories of rainfall that were more consistent with climate change models at the time, than with the actual observed rainfall for that period. It could be that these farmers were motivated to remember the past weather events in a way that conforms with their beliefs about climate change.

More recently, Hennes et al. (2016) manipulated participants' dependence on the financial system by presenting them with an article emphasising the extent to which citizens' lives are determined by the American economic system. Individuals made to feel more reliant on the system defended it more rigorously and in turn misremembered scientific facts in a way that was consistent with climate change denial. In a second study, Hennes et al. (2016) were able to demonstrate that an individuals' own dispositional level of system justification also affected recall of climate change related facts, notably participants high in system justification displayed biases in recall that facilitated scepticism. The researchers found that even when individuals are presented with scientific evidence concerning climate change, they are able to process the facts in a way that enables scepticism. They argue that acknowledging the occurrence of man-made climate change would infer problems with the current structuring of the economic system, therefore people higher in economic system justification are likely to be sceptical of scientific fact. These individuals are motivated to interpret evidence in a self-serving way that does not conflict with their pre-existing or manipulated beliefs, in this case, about the economic system. This study, and the research by Weber (1997) demonstrate how motivated reasoning can lead to motivated memory both after a short duration and in the long-term.

Furthermore, one's views about the world and how it should be structured have been shown to enact climate change scepticism. Cultural Cognition Theory (Douglas & Wildavsky, 1982; Kahan, 2012) uses group (individualistic vs. communitarian) and grid (hierarchical vs. egalitarian) facets to identify different types of worldviews. "Group" can refer to how people view government intervention in the everyday lives of the lives of the individual; one would identify as individualistic if they are against collective interference, while people who favour greater collective attention to individual needs are suggested to be communitarian. "Grid" denotes how individuals believe the social hierarchy should be; people who tie authority to social rankings are said to be hierarchical, whereas individuals who prefer a less rigid structure are egalitarians. When investigating how these pre-existing values relate to climate change scepticism, researchers found that people subscribing to a hierarchical and individualistic worldview rated climate change risks significantly lower than people with an egalitarian and communitarian worldview (Kahan et al., 2012).

These worldviews also relate to individuals' perceptions of scientists and the scientific consensus on climate change. Kahan et al. (2011) asked participants to rate the credibility and trustworthiness of three experts on climate change, gun control, and nuclear waste disposal respectively. The biggest disparity between the participants with different worldviews was seen for the climate change scenarios; the researchers found that when the expert was taking a high-risk position (i.e., climate change is occurring now due to human activity), 88% of egalitarian communitarians believed he was credible, compared to just 23% of hierarchical individualists. When the expert took a low risk position (i.e., there is not enough evidence to say that greenhouse gasses are causing climate change), 86% of hierarchical individualists and 47% of egalitarian communitarians believed they were credible. The results show that hierarchical and individualistic people rate the credibility of the scientists as much lower than egalitarian communitarians, if what they are communicating threatens their views about the world. Interestingly, Dieckmann et al. (2017) analysed group and grid elements separately and demonstrated that the hierarchy-egalitarian (grid) dimension displayed a stronger relationship with climate beliefs than did the individualism-communitarian (group) facet.

As previously mentioned, one of the criteria used to obtain the "optimal" uncertainty expression for communicating facts about climate change is whether it leads to motivated evaluation resulting in biased inferences (Dieckmann et al., 2017). This could be taken one step further and applied to motivated memory. Single bound probability statements can be relatively ambiguous; they leave room for a certain amount of audience interpretation which may be more pronounced if individuals are very sceptical of scientists or have strong hierarchical and individualistic worldviews. Although a plethora of research exists that focusses on the relationship between worldviews and climate change scepticism, to my current knowledge, no studies have investigated how worldviews described by Cultural Cognition Theory affect recall of climate change related facts after a delay. It is hypothesised that hierarchical and individualistic persons will rate the credibility of scientists' forecasts as low, and will subsequently remember the probability estimates to be smaller than they actually were.

1.3 Research aims and hypotheses

The main focus of the current thesis is to investigate how best to communicate the uncertainty around climate change, and specifically how single bound probability statements are interpreted, evaluated and remembered after a delay. The thesis will focus explicitly on

exclusive single bound probability statements (i.e., “more than 60%” vs. “less than 60%”), due to the belief that they will elicit stronger results than inclusive (minimum 60% vs. maximum 60%) statements. A within-subjects design will be utilised in order to directly compare how upper and lower bound statements are evaluated.

An evaluation task will be used to determine how credible individuals find scientists’ forecasts about climate change outcomes, depending on whether they view upper or lower bound probability statements. A recall task will also be utilised to investigate whether individuals use gist representations when remembering facts about climate change, and whether single bound probability estimates influence people to recall altered probabilities in line with the direction of the moderating statement.

The lack of research surrounding recall of climate change information presents an exciting and novel opportunity to not only look at single bound probability statements as a method of communicating uncertainty, but also to further investigate the idea of motivated memory. By utilising the evaluation and recall tasks in conjunction with measures of climate change belief and worldviews, I hope to shed light upon motivated reasoning and a possible motivated memory by which individuals with certain values and beliefs may distort their memories of facts in order to self-serve and satisfy their pre-existing ideologies.

There are various hypotheses for the current study which can be parted into two groups. One pertaining to the interpretation, evaluation, and subsequent recall of single bound probability estimates, and the other investigating the idea of motivated evaluation and motivated memory, and how single bound probability estimates may facilitate this.

Regarding single bound probability statements, the first hypothesis (H1) is that in the measure of credibility, people will view the scientists’ forecasts as more credible if they receive lower bound (more than) probability estimates and less credible if they receive upper bound (less than) probability estimates. The second hypothesis (H2) pertains to the idea of gist representations, and states that in the recall test, people will rely on gist interpretations of the single bound probability statements. The direction of the single bound statement (i.e., the verbal terms “more than” or “less than”) will be more accurately remembered than the verbatim numerical probability. The third hypothesis (H3) encompasses the idea of being influenced by the directionality of the gist, and states that in the recall test, people will be influenced by the exclusive statements to recall probabilities in line with the direction of the single bound statement (i.e., they will be influenced by the lower bound to give a probability greater than the original number they received, and by the upper bound to give a probability less than the original number).

Regarding motivated memory, the fourth hypothesis (H4) suggests that in the measure of credibility, the scientists' forecasts will be viewed as less credible by people whose worldviews oppose their statement (i.e., people subscribing to hierarchical and individualist worldviews). The fifth hypothesis (H5) states that in the recall test, people will remember lower numbers consistent with climate change scepticism if their worldviews oppose the stated facts (i.e., hierarchical and individualistic people will remember lower probabilities, egalitarian and communitarian individuals will remember higher probabilities).

2 Study 1

It is important to note here that originally, Study 1 included investigation into how individuals remembered point and interval estimates, in addition to lower and upper bound probability statements. The point and interval scenarios are included in the method section in order to be completely clear about how the study was structured, however they are excluded from the results section. All analyses on the point and interval scenarios were conducted separately from the analyses on single bound probability statements, therefore its removal does not compromise any of the reported results. I chose to focus specifically on one topic because of constraints on the length of the thesis; the single bound probability statements displayed the best internal consistency and generated the most novel and interesting results, ergo they were selected over intervals.

2.1 Method

2.1.1 Ethics

Participants were shown a consent form and information sheet before they began the study (see Appendix A). These forms detailed the nature of the research and included guidance about the participant's ethical rights, such as confidentiality and right to withdraw. They were informed that their answers would be used purely for scientific analysis. No risks to the participant from this study were identified.

2.1.2 Participants

In total, 140 participants took part in this study, however after removal of outliers, 101 participants were left for analysis. Data from thirty-nine participants was excluded due to unfinished questionnaires, extreme timing outliers, or unrealistic answers in the memory task (e.g., stated a probability of 120%).

All participants were residents of the United States and were recruited via Amazon's Mechanical Turk. Participants were reimbursed $0.75 for their time completing the study. Fifty-two (51.5%) participants were randomly allocated to condition A, and 49 (48.5%) participants were in condition B.

The age of the participants ranged from 21 to 67 with a mean age of 37.9 (*SD* = 11.40); 55 participants (54.5%) were male and 46 (45.5%) were female.

2.1.3 Materials and Procedure

The survey was designed using Qualtrics (2013). Participants had the option to complete this survey either on their computers or smartphones. Individuals were first shown the consent page on which the terms of participation were laid out; if they agreed with these terms they were then shown the information page describing some basic points about the study. Note that the participants were *not* informed that the purpose of the study was to investigate their memory for uncertainty statements, this was so that I could be reasonably sure that people did not cheat or write down the correct answers.

Participants were then randomly allocated to either condition A or condition B and presented with four scenarios (Table 1). After reading each scenario participants completed a picture-rating task where they indicated on a seven-point Likert scale how well the picture fitted with the scenario. The scale ranged from one "Not at all well" to seven "Extremely well". This was to disguise the true focus of the study, while also ensuring that the participants read and understood each scenario. Four photographs were obtained from unsplash to use in the picture-rating task (see Appendix B).

All participants in this experiment were exposed to both point and interval estimates, as well as lower bound (more than) and upper bound (less than) probability estimates in the different scenarios. All participants saw the sea level scenario first, followed by the lightning, polar bear and temperature scenarios.

Table 1

Breakdown of condition A and B in Study 1

	Scenarios			
	Sea level	Lightning	Polar bear	Temperature
Condition A	Point	Interval	More than	Less than
Condition B	Interval	Point	Less than	More than

Scenarios concerning sea level rise, lightning escalation, polar bear decline, and temperature increase were obtained from reputable climate change sources and were adapted slightly to fit the purposes of the current study. In the sea level scenario participants saw either a point or interval prediction concerning sea level rise: "Although different climate models give somewhat different predictions, a climate scientist, Dr. Seaworth, concludes we can expect the oceans to rise by 24 inches [12-36 inches] by 2100". Participants who received a point prediction in the sea level scenario received an interval estimate in the lightning

scenario and vice versa (see Appendix C for point and interval scenarios). For the polar bear scenario participants were presented with either a lower bound (more than) or upper bound (less than) probability estimate: "Based on data from several models, a Canadian research group predicts that two thirds of polar bears in this area will become extinct by 2050. Another climate scientist, Dr. North, states that it is more than 60% [less than 60%] likely that this prediction will come true." Those who received the lower bound estimate in the polar bear scenario received the upper bound estimate in the temperature scenario and vice versa (see Appendix D for upper and lower bound scenarios).

After reading the scenarios and rating the pictures for each scenario, participants were given two questionnaires that examined pre-existing views on cultural cognition and climate change respectively, and a demographics form that included items about age, gender, and levels of education.

The long form of the Cultural Cognition Worldview Scale (CCWS; Kahan, 2012; see Appendix E) comprises of 30 items in total and has two subscales that consist of group (individualism and communitarianism) and grid (hierarchical and egalitarian) facets. Items are measured on a six-point Likert scale that ranges from one "Strongly disagree" to six "Strongly agree". In this study the CCWS was found to have good internal consistency (α = 0.96).

Beliefs about global climate change were assessed using items modified from Heath and Gifford's Free Market Ideology questionnaire (2006; see Appendix F). Included were four items that assessed the belief that global climate change is occurring, measured on a five-point Likert scale from one "Strongly disagree" to five "Strongly agree", four items that measured beliefs in its causes and four items about its possible consequences. Due to a processing error the latter two were assessed using a six-point Likert scale ranging from one "Strongly disagree" to six "Strongly agree". Thus, the scores were standardised to check the internal consistency which was shown to be good (α = 0.91).

Participants completed the demographics form followed by the CCWS and the questionnaire assessing climate change beliefs. This section was deliberately placed in the middle of the questionnaire to introduce some delay between reading the scenarios and answering the memory questions. On average, participants spent 236 seconds responding to this section.

Following on from this, participants received three questions per scenario, that measured how certain and pessimistic they believed the scientist to be, and how severe they perceived the forecast to be (e.g., "Based on Dr. North's statement, how severe does the

situation seem for the polar bear population in Hudson Bay?"; see Appendix G for evaluation questions). Items were measured on seven-point Likert scales from one "Not at all certain/ pessimistic/ severe" to seven "Extremely certain/ pessimistic/ severe". The internal consistency of these items for the sea, lightning, bear and temperature scenarios were α = 0.53, 0.66, 0.79 and 0.75 respectively.

Following on from the evaluation task, participants completed the memory task where they were shown the scenarios once more with the points, intervals, and single bound probabilities excluded (see Appendix H): "Based on data from several models, a Canadian research group predicts that two thirds of polar bears in this area will become extinct by 2050. Another climate scientist, Dr. North, states that it is _____ likely that this prediction will come true". Underneath the text was a box where participants could fill in the answer they believed was in the original scenario. They also scored how confident they were in their answer on a seven-point Likert scale from one "Not at all confident" to seven "Extremely confident".

An attention check was also included at the end of the study, in order to flag participants who failed to read instructions carefully.

After completion of the study participants were again shown a brief description of the research and were provided with the email of the Principal Investigator should they have any questions (see Appendix I for debrief screen). They were also given the opportunity to write a comment about the research.

2.2 Results

2.2.1 Worldviews and ideologies

Results from the CCWS indicate that the distribution was clustered mainly around the centre for both group (M = 3.48, SD = 1.07), and grid facets (M = 2.86, SD = 1.18), where a score of one indicates a communitarian or egalitarian worldview and six indicates an individualistic or hierarchical ideology.

Results from the climate change questionnaire adapted from Heath and Gifford (2006) found that only 14 people (13.9%) stated that they strongly believed climate change was occurring now. Regarding cause and effect of climate change, 24 people (23.8%) strongly agreed that humans were to blame and 22 people (21.8%) strongly agreed it would result in negative consequences.

2.2.2 Evaluation of researcher credibility

To determine the effects of upper bound and lower bound probability estimates on ratings of certainty, pessimism and severity, a mixed analysis of variance (ANOVA) with condition as between-subjects factor and scenario as within-subjects factor was carried out. Since each participant received both a lower bound (more than) and an upper bound (less than) statement, but in different scenarios, I accordingly expected to see an interaction between condition and scenario. Additionally, for each scenario the three items were averaged into one variable measuring "credibility" of the researchers' forecast. The results indicated that condition seemed to influence how participants viewed the overall credibility of the scientists' prediction ($F(1,99) = 16.29$, $p < .001$). Specifically, the researcher received higher credibility ratings when giving a prediction featuring "more than X%" rather than "less than Y%". "More than" elicited higher ratings of certainty and severity across both scenarios, and higher ratings of pessimism were observed in the polar bear scenario (see Table 2 for an overview of separate ratings as well as for the overall credibility measure). There was no main effect of scenario observed, meaning that ratings of credibility were not dependent upon the stated probabilities, possibly because the two scenarios featured probabilities of a similar magnitude (60% in the polar bear scenario and 70% in the temperature scenario).

These findings offer support for Hypothesis 1, which stated that individuals will view a scientists' forecast which uses a lower bound statement as more credible than one using an upper bound statement.

Table 2

Descriptive statistics are displayed for the ratings of scientist certainty, pessimism and severity. Results from the ANOVA measuring the interaction between scenario and condition are also shown. Descriptive statistics and ANOVA results from the standardised global measure of credibility are reported. Note that no main effect of condition was observed

	Polar bears *M* and *SD*		Temperature *M* and *SD*		*F*	*p*	η^2_p
	More than	Less than	More than	Less than			
Certainty	5.13 (1.19)	4.78 (1.50)	5.63 (1.04)	4.71 (1.43)	16.33	.000	.142
Pessimism	5.02 (1.52)	4.16 (1.72)	4.69 (1.84)	4.71 (1.59)	5.68	.019	.054
Severity	5.56 (1.24)	4.84 (1.45)	5.71 (0.98)	5.00 (1.53)	16.49	.000	.143
Global Credibility	5.24 (1.01)	4.59 (1.37)	5.35 (1.01)	4.81 (1.31)	16.29	.000	.141

2.2.3 Free-recall task

Whilst many participants correctly recalled the verbatim numerical probability in the upper and lower bound conditions, it is important to note that only four participants in the polar bear scenario, and seven in the temperature scenario remembered the verbal direction of the probability (i.e., more than/ less than).

The percentage of participants who remembered the verbatim probability and the gist single bound statement is shown in Table 3 below. Participants were coded as having remembered the verbatim if their written response corresponded with the numerical probability stated in the original text, and the gist if they recalled the direction of the single bound statement.

The fact that very few participants recalled the single bound statement is in contrast to Hypothesis 2, which stated that participants would more easily remember the gist direction of the statement than the verbatim numerical probability.

Table 3

Percentage of participants who remembered the verbatim numerical probability and the gist single bound statement in the free-recall task

	Polar bears		Temperature	
	More than	Less than	More than	Less than
Verbatim recall (%)	44.23	63.27	48.98	40.38
Gist recall (%)	1.92	8.16	8.16	5.77

To enable the most accurate analysis of the free-recall task, the distance between the correct numerical probability and each participants' answer was calculated. For example, in the bear scenario, where the verbatim probability is 70%, an answer of 40% would yield a distance of -30 (since it is 30% lower than the verbatim answer).

A mixed ANOVA was carried out in order to determine whether the direction of the single bound statements influenced participants to remember higher or lower probabilities. The distances from the verbatim answer were standardised in order for them to be compared accurately, and the results from both the standardised and unstandardised scores can be seen in Table 4. No significant interaction effects were found between condition and scenario. A main effect of scenario was observed ($F(1,99) = 31.96$, $p > .001$), which when analysed further, revealed that participants were actually recalling similar probabilities for both scenarios.

Table 4

Descriptive statistics for original and standardised (Z) scores showing the mean distance from verbatim probability in the polar bear and temperature scenario are displayed. Mixed ANOVA results measuring the interaction between scenario and condition on the mean distance are also shown. A main effect of scenario was observed (F(1,99) = 31.96, p >.001)

	Polar bears *M* and *SD*		Temperature *M* and *SD*		*F*	*p*	η^2_p
	More than	Less than	More than	Less than			
Original score	-0.08 (13.78)	-1.84 (13.10)	-10.08 (16.32)	-12.42 (20.50)	1.27	.263	.013
Z score	.064 (1.03)	-0.07 (0.98)	0.07 (0.88)	-0.06 (1.11)	1.35	.248	.013

These findings are at odds with Hypothesis 3 which posited that individuals would be "primed" by the directionality of the lower and upper bound statements to answer in a specific way.

2.2.4 Correlation between worldviews and credibility ratings

Results from a Pearson's bivariate correlation revealed that individuals who are more hierarchical and individualistic are also sceptical that climate change is occurring now (Table 5). No significant correlations were identified between these variables and the evaluation of researcher credibility, contrary to the expectations of Hypothesis 4, which stated that hierarchical and individualistic people would view the climate scientists' forecasts as less credible.

Table 5

Pearson's r correlation matrix to show the relationship between worldviews and climate change beliefs

	Climate change beliefs		
	Occurring now	Human causes	Negative consequences
Individualistic	-.572***	-.628***	-.571***
Hierarchical	-.618***	-.705***	-.600***

2.2.5 Correlation between worldviews and memory task

A Pearson's bivariate correlation was performed in order to identify correlations between worldviews, beliefs about climate change, and the distances from the verbatim probability in the free-recall task. No significant relationships between any of these variables were observed. These results offer no support for motivated memory, opposing Hypothesis 5.

3 Study 2

In Study 2, in addition to upper and lower bound statements, wide versus narrow intervals were investigated. Correspondingly to Study 1, in order to be transparent, the scenarios are reported in the method section, however they were removed from analysis. Again, all results were conducted separately, therefore no findings are compromised.

In the second study a number of changes were made to improve the experiment. Firstly, the evaluation questions were elaborated to include additional and more specific questions. In Study 1, the results from the free-recall task indicated that participants did not remember, or were not reporting, the single bound statements. In order to investigate this in more detail, a recognition task, where the original statements were included as one of several alternatives, was employed alongside the free-recall task. Lastly, the probabilities in the upper and lower bound scenarios were changed to enable comparison of probabilities with a greater disparity.

3.1 Method

3.1.1 Participants

Similarly to Study 1, 134 participants were recruited from Amazon Mechanical Turk and given $0.75 for their time. After outlier removal, 92 participants remained for analysis; of these 48 (52.2%) and 44 (47.8%) were randomly allocated to condition A and B respectively. The male to female ratio was equally split with 46 males and 46 females taking part. The ages of the participants ranged from 21 to 60, with a mean age of 34.6 (SD = 9.72).

3.1.2 Materials and Procedure

The materials and procedure were generally the same as in Study 1. Once again, paragraphs about sea level, lightning, polar bears, and temperature were used in this study, however the point and interval scenarios were substituted for wide and narrow intervals (see Appendix J for wide and narrow interval scenarios). The probability estimate was changed from 60% to 70% in the polar bear scenario and the temperature probability was changed from 70% to 40% (see Appendix K for upper and lower bound scenarios). I selected probabilities that were more divergent in order to determine whether the ratings of credibility were influenced by the specific probability estimate, as well as the single bound statement, and also to limit participants' confusion between the two estimates that seemed to be occurring during the Study 1 recall task.

In this study, the scenarios were presented in a completely randomised order where any of the four scenarios could be shown first; this was to minimise the influence of order effects. A breakdown of the two conditions is shown below (Table 6).

Table 6

Breakdown of condition A and B in Study 2

	Scenario			
	Sea level	Lightning	Polar bear	Temperature
Condition A	Wide	Narrow	More than	Less than
Condition B	Narrow	Wide	Less than	More than

The same photographs for the picture rating task, demographics form and CCWS (Kahan, 2012) that were used in Study 1 were once again employed here. The CCWS was found to have good internal consistency in this study ($\alpha = 0.96$).

The items measuring beliefs about climate change adapted from Heath and Gifford's (2006) questionnaire were also used, however in this study climate change causes and consequences were measured on a five-point Likert scale from one "Strongly disagree" to five "Strongly agree". The internal consistency of this questionnaire in Study 2 was found to be good ($\alpha = 0.95$).

After completing the demographics section, six evaluation questions assessed participants' views on the scientists' predictions regarding each scenario (see Appendix L for the evaluation questions). The six items were measured on a seven-point Likert scale from one "Strongly disagree" to seven "Strongly agree". The items assessed how sure the speaker was believed to be, how severe the consequences were deemed to be and whether the speaker was thought to be exaggerating or making a bold prediction. The internal consistency of these items for sea level, lightning, polar bears and temperature were $\alpha = 0.75$, 0.68, 0.80 and 0.77 respectively.

In addition to the free-recall task commissioned in Study 1; participants completed a recognition task where they selected the original prediction from a series of options (see Appendix M for examples of the recognition task). For example, in the sea level scenario participants were shown four options in a randomised order: The wide interval (4 to 39 inches), the narrow interval (18 to 25 inches), and two alternatives that represented the lower and upper boundaries of the intervals (4 to 25 inches, 18 to 39 inches). For the polar bear scenario participants could select from 12 items that included four different number choices

(80%, 70%, 50%, 30%) combined with one of three distinctive moderating statements (more than, less than, about).

3.2 Results

3.2.1 Worldviews and ideologies

In this study, results from the CCWS indicate that the distribution was again clustered mainly around the centre for both group (M = 3.45, SD = 1.00), and grid facets (M = 2.62, SD = 1.20).

Results from the climate change questionnaire found that 16 people (17.4%) stated that they strongly believed climate change was occurring now. Regarding cause and effect of climate change 28 people (30.4%) strongly agreed that humans were to blame and 19 people (20.7%) strongly agreed it would result in negative consequences.

3.2.2 Evaluation

For both the polar bear and temperature scenarios, the six evaluation questions were combined into one measure assessing credibility of the scientists' forecast. To do this, the negatively worded questions were reverse coded. Multiple mixed ANOVAs were then performed to identify the effect that condition had on participants' ratings of credibility in the evaluation task. Again, I expected to observe an interaction between condition and scenario, since each participant saw both a lower bound (more than) and an upper bound (less than) statement in the different scenarios. Results for all individual questions as well as the overall measure of credibility are displayed in Table 7. A significant interaction effect of condition and scenario on the overall rating of credibility was found (Table 7). There was also a main effect of scenario reported for the global measure of credibility, meaning that participants rated the scientists' credibility significantly differently between the scenarios. This occurred presumably due to much a higher numerical probability in the polar bear scenario (70%) compared to the temperature scenario (40%). It is evident from Table 7, that there was much more disparity amongst the ratings for the temperature scenario than the polar bear scenario; the single bound statement seemed to have more of an effect on ratings of credibility for the researchers' forecast when coupled with a low numerical probability in the temperature scenario.

This finding offers support for Hypothesis 1, showing that the "more than" condition elicited higher ratings of credibility, but also indicates that higher probabilities lead to increased ratings of credibility compared to lower probability estimates.

Table 7

Descriptive statistics are shown for the six individual evaluation questions and the global credibility ratings in both the polar bear and temperature scenarios. Results from the ANOVA measuring the interaction between scenario and condition are also displayed. For the global credibility rating, a main effect of scenario is reported ($F(1,90) = 6.03$, $p = .016$, $\eta^2_p = .063$)

	Polar bears *M* and *SD*		Temperature *M* and *SD*		*F*	*p*	η^2_p
	More than	Less than	More than	Less than			
Exaggerating	2.81 (1.78)	2.57 (1.44)	2.32 (1.10)	2.90 (1.55)	1.25	.267	.014
Sure	5.15 (1.24)	4.89 (1.10)	4.70 (1.32)	4.06 (1.49)	8.56	.004	.087
How bad	5.35 (1.39)	5.04 (1.44)	4.82 (1.63)	4.44 (1.57)	3.44	.067	.037
Not so severe	2.46 (1.49)	2.50 (1.64)	2.32 (1.30)	2.94 (1.63)	4.06	.047	.043
Does not know	2.58 (1.38)	2.68 (1.48)	2.59 (1.25)	3.50 (1.65)	8.99	.004	.091
Bold and risky	3.44 (1.86)	3.45 (1.64)	3.46 (1.43)	3.35 (1.63)	0.39	.533	.004
Global Credibility	5.20 (1.11)	5.12 (1.01)	5.19 (0.82)	4.64 (1.11)	10.06	.002	.101

3.2.3 Free-recall task

As with Study 1, very few participants remembered the verbal statement; just 10 in the polar bear scenario, and six in the temperature scenario. The number of people who freely remembered the verbatim numerical probabilities and gist single bound statements is shown below in Table 8.

These findings are not in line with Hypothesis 2, which suggested participants would remember the gist of the statement (more than/ less than) with more ease than the verbatim probability estimate.

Table 8

The percentage of participants who remembered the verbatim numerical predictions and gist single bound statements

Condition	Polar bears		Temperature	
	More than	Less than	More than	Less than
Verbatim recall (%)	54.19	59.10	59.10	45.83
Gist recall (%)	2.08	20.45	9.09	4.16

Once again, the distance from the correct answer was calculated. Mixed ANOVAs were performed to investigate the effect of upper and lower bound statements on the distance participants' answers were from the verbatim probability estimate (Table 9). Correspondingly to Study 1, no significant interaction effect was found, suggesting that viewing upper or lower bound probability estimates does not lead people to recall different numerical probabilities. A main effect of scenario was observed ($F(1,90) = 6.03$, $p = .016$, $\eta^2_p = .063$). For the polar bear scenario, participants remembered, on average, probabilities that were lower than the verbatim 70%, whilst for the temperature scenario probabilities above the verbatim 40% were remembered, regardless of condition.

These findings offer no support for Hypothesis 3, which suggests individuals would recall probabilities that were in line with the directionality of the modifying single bound statement.

Table 9

Descriptive statistics for the original and standardised (Z) scores demonstrating distance from the stated probability in the polar bear and temperature scenarios are displayed. Mixed ANOVA results for the interaction effect between scenario and condition on distances from the verbatim probability are shown. A main effect of scenario was observed ($F(1,90) = 51.55$, $p < .001$)

	Polar bears *M* and *SD*		Temperature *M* and *SD*		*F*	*p*	η^2_p
	More than	Less than	More than	Less than			
Original score	-11.23 (18.08)	-6.77 (15.54)	7.84 (15.07)	8.35 (15.62)	1.09	.300	.012
Z score	-0.13 (1.07)	0.14 (0.92)	-0.02 (0.99)	0.02 (1.02)	1.01	.318	.011

3.2.4 Recognition task

Table 10 shows the results from the cross tabulation of answers to the recognition task in the polar bear scenario. It is evident that the majority of participants in both condition A and B were able to recognise the verbatim numerical probability from a series of distractors. However, they did not fare so well identifying the verbal cue; only 12 participants recognised the lower bound and 28 recognised the upper bound in the polar bear scenario (Table 10).

Table 10

The number of people who selected specific answers in the polar bear recognition task are displayed. Results are broken down by verbal and numerical answers. Quantities in bold font correspond to the number of participants per condition who selected an option that included either the original verbal or numerical answer

	Recognition task	Condition	
		More than	Less than
Verbal	Less	6	**28**
	About	30	12
	More	**12**	4
Numerical	30%	6	3
	50%	5	8
	70%	**33**	**30**
	80%	4	3

Again, for the temperature scenario the majority of people recognised the verbatim numerical probability, however, only 15 people selected the stated lower bound and 18 recognised the upper bound (Table 11).

These findings suggest that the participants were not attending to the upper and lower bounds (the gist) of the probability estimate. Instead they were better able to select the verbatim numerical probability from a series of distractors. The results are in contrast to Hypothesis 2, which stated that the gist would be better remembered.

Table 11

The number of people who selected specific answers in the temperature recognition task are displayed. Results are broken down by verbal and numerical answers. Quantities in bold font correspond to the number of participants per condition who selected an option that included either the original verbal or numerical answer

	Recognition task	Condition	
		More than	Less than
Verbal	Less	9	**18**
	About	20	24
	More	**15**	6
Numerical	20%	2	3
	40%	**30**	**29**
	60%	8	11
	80%	4	5

3.2.5 Correlation between worldviews and credibility ratings

To examine the possible relationship between worldviews and the perceived credibility of the researchers' forecast, a Pearson bivariate correlation was performed using the global measure of credibility. As evidenced by Table 12, hierarchical and individualistic beliefs, as measured by the CCWS (Kahan, 2012), displayed negative correlations with researcher credibility, suggesting that participants who possess these beliefs about the world are more sceptical of climate change scientists' forecasts. The climate change scores calculated from Heath and Gifford's (2006) measure correlate positively with credibility ratings. This suggests that participants who accept the scientific consensus on climate change are more likely to trust rulings from experts.

These findings offer support for Hypothesis 4, demonstrating that worldviews and beliefs affect how individuals rate the credibility of climate scientists' forecasts.

Table 12

Pearson's r correlation matrix to show relationship between worldviews, climate beliefs and perceived credibility of researchers' forecasts in both the bear and temperature scenarios

Ideology	Worldview		Global Credibility	
	Individualistic	Hierarchical	Polar bears	Temperature
Individualistic	-	-	-.372***	-.246*
Hierarchical	.718***	-	-.482***	-.351***
CC occurring now	-.520***	-.599***	.454***	.330***
CC human causes	-.535***	-.737***	.564***	.477***
CC negative consequences	-.513***	-.714***	.562***	.520***

*Note. * p < .05, **p < .01 and *** p < .001*

Key: CC occurring now = Belief that climate change is happening currently, CC human causes = Belief that climate change is man-made, CC negative consequences = Belief that the results of climate change will be negative

3.2.6 Correlation between worldviews and memory tasks

Similarly to Study 1, no support for the idea of motivated memory in regards to worldviews was found in the free-recall task. Additionally, no evidence was found corresponding to the verbal part of the recognition task.

To determine whether worldviews and beliefs about climate change correlate with how participants answered in the numerical part of the recognition task, a Pearson's bivariate correlation was performed. Only two items displayed significant correlations with numerical recognition scores in the polar bear scenario, these were hierarchical worldview (r = -.22, p = .036), and belief that climate change is occurring now (r = .24, p = .020). There were no significant correlations in the temperature scenario. However, for both the polar bear and temperature scenarios patterns were observed in an expected direction; high individualistic and hierarchical scores correlated negatively with answers in the numerical recognition task, suggesting that participants with these worldviews selected lower numbers on the recognition task. The opposite was true for measures of belief in climate change. However, since all but two of these correlations failed to reach significance, one cannot conclude that there is a relationship between worldviews, beliefs about climate change and answers selected in the recognition task. Therefore, the results indicate no support for the existence of motivated memory, contrary to Hypothesis 5.

4 Discussion

4.1 Single bound probability statements

4.1.1 Evaluation task

This thesis primarily examined how so called single bound probability estimates are interpreted, evaluated and subsequently remembered after a short delay. In accordance with Hypothesis 1, in both Study 1 and 2, it was found that participants evaluated lower bound probability estimates (more than) in a way that assigned more credibility and trust to the speakers' forecast, as compared to upper bound probability statements (less than). Participants were able to draw multiple pragmatic implications from the scenarios in the current studies as evidenced by the results from the evaluation task. Inferences about the scientists were made, including how certain, pessimistic, and knowledgeable they seemed. Scientists who gave upper bound probability estimates were seen to be uncertain and unsure of the information that they were communicating. Conclusions about the severity of the situation were also extrapolated from the prediction the scientist gave; in both studies, participants who were presented with "less than" estimates interpreted the polar bear and temperature scenarios as less severe than participants who received "more than" estimates.

In Study 2 these results are more pronounced in the temperature scenario compared to the polar bear scenario. It seems likely that this may be because participants here had the opportunity to directly contrast numerical probabilities of different magnitudes (40% in the temperature scenario and 70% in the bear scenario). Thus, in comparison to a low probability, a high probability would presumably receive relatively high ratings regardless of the verbal term. A low probability however, may seem even lower when associated with an upper bound term, but more acceptable when associated with a lower bound term. Hohle & Teigen (2018) discuss how probabilities pertaining to severe risk (e.g., climate change) can be perceived as very high even when they are below 50%. The addition of a lower bound moderating statement may accentuate this effect. Future research would benefit by directing attention to the effect of single bound statements on probabilities below 50% and by investigating how people compare such probabilities to ones that are above chance occurrence.

Since the studies utilised a within-subjects design, the participants were able to compare the two probability estimates, as well as the different single bound statements. There was no main effect of scenario on credibility ratings observed in Study 1, meaning that participants rated the credibility of the scientists' forecasts as roughly the same across the

scenarios. This was most likely due to the probabilities being quite close in quantity (60% in the polar bear scenario and 70% in the temperature scenario). In Study 2 however, participants did rate the credibility of the experts differently between the two scenarios, the scientists' forecast in the polar bear scenario was deemed more credible than in the temperature scenario, possibly because it utilised a significantly higher probability. Participants' ratings of credibility were shown to depend on both the single bound statement and the probability estimate that the scientists gave, demonstrating that the participants were assigning weight to both the verbatim numerical probability and the gist directional statement.

One of the criteria that exist to determine the best possible method of uncertainty communication regarding climate change pertains to how well the audience comprehends the expression. In the current studies participants were able to make pragmatic inferences about the scenarios, even after a delay, suggesting that they understood the single bound probability estimates. Although in Study 2 it is clear that the participants were able to recognise a difference between 70% and 40%, the interaction effect demonstrates that they were also noticeably affected by the single bound statement. These findings together indicate that, in Study 2 at least, the participants were attending to the verbal and numerical part of the probability statement, suggesting that they were comprehending both parts of the estimate. However, this may not be completely advantageous; the fact that an interaction effect was observed highlights how strategic communicators could use "less than" to downplay a risk that is arguably large, or "more than" to exaggerate a small risk. Speakers may be able to manipulate their listeners to think a certain way by choosing a single bound that frames the probability estimate as either high or low chance.

The existence of an interaction effect between condition and scenario, clearly shows that the type of statement (upper vs. lower bound) influences how much credibility participants assigned to experts' forecasts. In both studies, participants were influenced by the single bound to make certain pragmatic inferences about the experts and the severity of the scenario. This has important implications, not only theoretically, by supporting the findings of previous research and demonstrating how single bounds are evaluated after a delay, but also practically, by illustrating how framing a probability in a particular way can lead an individual to view serious risk information as a credible threat or as an exaggerated phenomenon.

4.1.2 Free-recall and recognition tasks

Despite the evidence that participants put substantial weight on the gist of the single bound statement whilst evaluating it, they failed to recall gist information in the free-recall task in either study; contrary to the expectations of Hypothesis 2. In Study 1, only four participants in the polar bear scenario and seven in the temperature scenario freely remembered that there was a verbal moderator preceding the probability. In Study 2, 10 participants in the bear scenario and six in the temperature scenario recalled the single bound, leading to the assumption that they had either forgotten it, or regarded it as insignificant.

When this was investigated further in the recognition task in Study 2, it became evident that even with prompts, participants were not recognising the upper and lower bound statements. For the temperature scenario, approximately double the number of participants identified the verbatim numerical estimate compared to the verbal statement in both the lower and upper bound conditions. In the lower bound condition for the bear scenario, 69% of participants identified the numerical probability from a list, whilst only one quarter recognised the correct verbal statement. In the upper bound condition however, the percentage of participants who remembered the specified numerical and verbal statements were relatively similar, with only a slightly greater percentage for the numerical estimate. Perhaps the use of an upper bound statement coupled with a high probability is one explanation for the increased recognition of the single bound statement in this particular condition, possibly because the combination is unexpected.

When it came to recognising the verbatim numerical estimate, participants were generally quite accurate (>60%), yet they were wholly inconsistent when identifying the gist and seemed to be swayed by the inclusion of "about". These findings are divergent from the hypothesised assumptions of Hohle and Teigen (2018), who suggest that the verbal part of the statement may be easier to recall than the verbatim numerical estimate. The researchers propose that individuals may be left with a sense of what the speaker wants to say rather than the verbatim probability level, finding it easier to remember the positive or negative tone of the statement.

Additionally, and in contrast to Hypothesis 3, no evidence was found suggesting that participants were influenced by the direction of the gist to recall numerical probabilities that were higher or lower than the verbatim in the free-recall task. In other words, participants did not recall numbers higher that the stated probability if they were presented with a "more than" statement, and vice versa for the "less than" statements. This finding becomes more

interesting if it is related to the fact that exclusive single bound statements were used (i.e., "more than" as opposed to "minimum"), since they are generally perceived to exclude the stated probability (Teigen et al., 2007). This may count as more evidence to suggest that participants were not putting much weight on the gist of the statement when recalling it, instead they focussed on the explicitly stated, verbatim quantity.

What is most interesting about these findings, is that during the evaluation tasks in both studies, participants were clearly influenced by the gist of the statement and were able to draw pragmatic inferences about the text that were significantly based on the positive or negative tone. Yet most seemed to have forgotten this gist when it came to the memory tasks, even when they were prompted with a recognition test. This is starkly different from research by Reyna (2004), who notes that when recalling information about risk, individuals rely heavily on gist representations and often completely forget the verbatim.

One explanation for the results found in the current studies are that the participants were "unconsciously" affected by the gist of the statement. It may be possible that the participants were paying more attention to the verbatim numerical probability whilst reading each scenario, yet they were instinctively affected by the pragmatic implications of the single bound statements. Study 2 revealed that participants were able to differentiate between the verbatim probabilities (as well as the gist directional statement) when they evaluated the scenarios, demonstrating that they were paying attention to them, and possibly giving more weight to this theory.

An alternative explanation is that, in fact, it is by evaluating and interpreting the scenarios, that individuals remember the gist of a statement (i.e., the pragmatic implications). Recalling the gist may not actually be through explicit recall. In the evaluation tasks, participants were able to rely on their overall impression in order to make pragmatic inferences about the scenarios, thus it may be the overall impression of the scenarios that becomes the gist. In the recall tasks, the participants may have believed that they were expected to give the verbatim numeric probabilities, supposing that they were somehow more important than the single bound statements. This may explain why so many participants chose "about" in the recognition task, they were more focussed on selecting the stated verbatim quantity.

It is important to note here, that although participants experienced a delay between reading the scenarios and recalling the single bound probability estimates, the interval was not particularly long. This could be considered a limitation, since the delay may not have been extensive enough to enable the verbatim probability to disappear from memory. People do not

often make decisions about climate change whilst reading information about it, yet they are also probably quite unlikely to make decisions about it five minutes later. In Lloyd and colleagues' (2001) study on recalling information regarding stroke risk and medical procedures, participants were surveyed one month after they were first presented with the statistics. It would be interesting to investigate how stable the effects identified in the current studies are, and whether researchers identify different findings regarding how people remember single bound statements after a longer time period (e.g., a few days or a week).

Concerning the criteria for effective uncertainty communication, the verbatim numerical probability seems to be the most salient part of the statement, remaining after a short delay. Though participants clearly remembered the gist of the statement whilst they were evaluating the scenarios, they had either disregarded or forgotten the positive or negative tone of the message during the memory tasks. This unexpected finding is one that warrants further longitudinal research since many scholars previously found that it is gist information which is most lasting (Reyna & Hamilton, 2001).

4.2 Motivated reasoning and motivated memory

4.2.1 Evaluation task

In both studies climate beliefs correlated with worldviews, supporting previous research by Kahan et al. (2012): People who score greater in hierarchical and individualistic worldviews tend to be more sceptical of climate change. Kahan et al. (2012) propose that this may be because such people want to keep their affinity within a social group, or they may believe that widespread acceptance of environmental risks would lead to constraints on commerce and industry, things that they place great value upon.

The relationship between traits and scepticism was investigated further by adding the overall score of credibility into the matrix. In the first study there was no evidence suggesting a relationship between worldviews and perceived credibility of scientists' forecasts, possibly because the evaluation questions were not specific enough. After refining the questions in Study 2, I was able to discern a relationship between the two variables. The global measure of scientist credibility correlated negatively with hierarchical and individualistic traits as measured by the Cultural Cognition Worldview Scale, (CCWS; Kahan, 2012) as did a number of specific evaluation sub-questions. The correlation revealed that participants who scored greater in hierarchical and individualistic traits construed the scenarios in a way that was self-serving to their pre-existing ideologies, choosing to disbelieve and discredit the scientists'

forecasts. This means that participants in Study 2 were using motivated reasoning when completing the evaluation task, offering support for Hypothesis 4.

Researchers state that when cultural cognition features in an individuals' reasoning, the person processes new information in a manner consistent with their prior beliefs, due to the motivation to protect one's identity and values (Kahan et al., 2011; Sherman & Cohen, 2006). Regarding this, Kahan et al. (2011) suggest that because of identity protective cognition, individuals are likely to start out with perceptions of certain risks that are associated with their cultural worldviews. In the face of new information, even if they intend to evaluate it without referencing pre-existing views, the individual will likely attend to it in a way that reinforces their prior beliefs.

Individuals more readily assign credibility and trustworthiness to communicators whom they perceive as having similar worldviews to their own, whilst denying expert knowledge to those whose worldviews are different (Kahan et al., 2011). This could explain why 85% of conservative Republicans are sceptical of the motives of climate scientists and believe their research cannot be trusted (Pew Research Center, 2016). When judging the credibility and trustworthiness of scientists in Kahan and colleagues (2011) study, participants' answers were dependent on the fit between the experts' opinion and their own position regarding their worldviews; this was true for both hierarchical individualists, and egalitarian communitarians. In Study 2, the scales of hierarchicalism and individualism, displayed highly significant negative correlations with the overall measure of credibility of scientists' forecasts, demonstrating that participants' high in these traits are denying trust and integrity to the experts. The current findings support the work of Kahan et al. (2011), illustrating that these individuals fit their perceptions of scientists' expertise to their pre-existing values. It is worth mentioning here that the grid facet displayed slightly stronger negative correlations with both the climate change measures and the ratings of credibility than did the group facet. This finding echoes the results from previous research, which identified that the hierarchical-egalitarian dimension was more strongly correlated with climate scepticism (Dieckmann et al., 2017).

Researchers further suggest that the individual who relies on prior beliefs to attend to new information, will either fail to change their mind about a topic or change it much slower than they should, because of the predisposition to assess and assign weight to information, including the opinions of scientists, based upon prior beliefs (Kahan et al., 2011). Such individuals must first decide whether a communicator has expertise and credibility before they determine whether to update their mental inventory of expert positions (Kahan et al.,

2011). This highlights the importance of investigating how people perceive climate scientists in relation to the possibility of changing attitudes. The present research adds to the body of knowledge suggesting that an individuals' worldviews determine how much stock they put in the predictions of climate scientists. To change the attitudes of climate sceptics, scientists may need to frame the information they present in a way that leads the individual to believe they possess similar views.

4.2.2 Free-recall and recognition tasks

In addition to evaluating the scenarios and the credibility of the scientists using motivated reasoning, it was also expected that participants would recall facts about climate change in a way that was biased towards their worldviews and beliefs. After correlating measures of ideology with the free-recall task, no such relationship was observed. The verbal statements in the recognition task also generated no significant results or observable pattern. The correlation between numerical recognition and ideology in Study 2 also produced mainly insignificant findings, with the exception of two significant results in the polar bear scenario pertaining to hierarchy and belief that climate change is currently occurring. The relationship between the other variables and numerical recognition in both the polar bear and temperature scenarios navigated in an expected direction (i.e., numerical recognition was negatively related to hierarchical and individualistic facets, and positively correlated with acceptance of climate change). However, these correlations were small, and they failed to reach significance.

One reason for the lack of significance could be that the subjects were generally quite accurate, especially during the recognition task. This left less than 40% of participants remaining who may have been susceptible to "motivated memory". It is possible that there were too few participants left to investigate in the sample, potentially leading to a lack of statistical power. Thus, the relatively small sample size in the present studies can be considered a limitation.

Due to the lack of significant results, the tests of memory that were chosen in the present studies warrant discussion. The only other study to focus on motivated remembrance of climate change information employed recall methods similar to those used in the current studies. Hennes et al. (2016) utilised open ended questions, where participants could answer freely, and multiple-choice questions, where subjects chose from two alternatives. The recognition task in Study 2 utilised three verbal, and four numerical alternatives, supposedly increasing the likelihood of incorrect recall and subsequent rise of motivated memory.

It is possible that there is more than one way for climate sceptics to display motivated memory. The most obvious (and the one hypothesised in the current thesis) being that climate sceptics believe the risk of climate change to be in line with their beliefs, so recall very low numbers. This relates heavily to the idea of reasoning motivated by the need to protect ones' cultural cognition and ideology, prescribed by Kahan et al. (2011). However, it is plausible that sceptics could also remember facts about climate change as being very high, since they may believe that climate scientists have a tendency for exaggeration and alarmist claims. It is possible that in the current thesis, sceptical participants were engaging in both types of biased motivated memory, thus the results were pulled in opposite directions, ultimately leading to null findings. It could be very interesting to further investigate the notion of multiple methods by which motivated memory can arise.

Although the patterns observed in the numerical recognition task were insignificant, it is still possible that a motivated memory for climate change information exists. Future research should seek to obtain a much larger sample size in order to fully investigate the possibility of motivated memory in this context. This is especially applicable if there are multiple ways for memory to be motivated.

4.3 Connecting single bounds with motivated reasoning

4.3.1 Directions for future research

Although the current studies failed to demonstrate the existence of motivated memory in relation to cultural worldviews and facts about climate change, it did generate some interesting findings regarding how individuals evaluate and attend to the information provided by single bound probability estimates.

By examining the suitability of the method to effectively communicate uncertainty it becomes evident that single bound estimates do allow for motivated evaluation. Study 2 illustrates how individuals high in particular worldviews may use the imprecise uncertainty conveyed by single bound probability estimates to evaluate them in a way that is consistent with their preconceptions and beliefs. The current thesis found that people with hierarchical and individualistic worldviews rate expert credibility as lower across scenarios and conditions, however it would be interesting to further investigate whether upper and lower bound statements amplify this effect. It may be reasonable to speculate that hierarchical individualists assign less weight to information that is uncertain or focus on just one part of the statement depending on whether it supports their point of view. For example, a

hierarchical and individualistic person may choose to focus on the "less than" part of an upper bound statement if the probability estimate is above chance (50%) occurrence. Researching this will add to the accumulating body of knowledge that has assessed how such people attend to various methods of communicating uncertainty around climate change (Deickmann et al., 2017; Kahan et al., 2011).

Single bound probability estimates are fairly ambiguous in the sense of how individuals interpret them. Dieckmann et al. (2017) suggest that communicators should seek as much as possible to limit the ambiguity of an uncertainty expression. In this vein, single bound probability statements are already superior to verbal expressions alone (e.g. "it is unlikely") since they adopt a numerical approach alongside a verbal moderating statement, partially limiting ambiguity; the combination of numerical and verbal estimates has been suggested to reduce the chance of motivated evaluation (Budescu, Por, & Broomell, 2012). Nevertheless, single bound probability estimates do not limit all ambiguity of interpretation. In fact, most methods for communicating risk information about climate change are likely to be ambiguous by their very nature, since the topic to which they are applied is inherently uncertain.

Hohle and Teigen (2018) suggest a probability range may reduce the imprecision of single bound probability estimates. However, Deickmann et al. (2017) found that the ambiguity pertaining how to interpret numerical and probability ranges allowed for much motivated evaluation. Participants who are sceptical of climate change and possess hierarchical and individualistic worldviews, interpreted the ranges to be uniform, with quantities at the lower end of the range more likely to occur. Egalitarians, communitarians, and acceptors of climate change believed the ranges to be normally distributed, with quantities at the higher end more likely to occur. It would be interesting to replicate part of Hohle and Teigen's (2018) study to investigate how cultural worldviews and prior beliefs about climate change relate to interpretation of single bound probability estimates, (i.e., what probability is anchored to the single bound estimate). Although the results from the memory tests do not support this idea, it may remain reasonable to suggest that, at the time of evaluation (i.e., no delay), hierarchical and individualistic persons would use the gist of a single bound probability estimate to interpret it as much lower than egalitarian and communitarian individuals (e.g., "less than 50%" may be translated by hierarchical individualists to mean 41%, and by egalitarian communitarians to be 49%). Future research should seek to compare single bound probability estimates with other methods of uncertainty communication, such as likelihood statements, ranges, and diagrams, in order to determine

which is most adept at reducing motivated evaluation. This could be a fruitful opportunity for exploration, offering valuable insights into how people with different cultural worldviews interpret single bound probability estimates in comparison to other methods, and allowing experts to choose the most suitable means to communicate the uncertainty around climate change.

4.4 Summarising remarks

This thesis piloted the concept of memory in relation to how single bound probability estimates are remembered, and whether specific cultural worldviews evoke biased recall of facts about climate change.

Interesting results were identified regarding how risk-communicating single bound probability estimates are evaluated and remembered after a delay. The novel findings show that participants used gist representations during evaluation and verbatim memory whilst recalling and recognising climate change related facts.

In conjunction with previous research (Kahan et al., 2011), I also found that individuals with dissimilar worldviews rate the credibility of scientists and their forecasts about climate change differently.

Although no significant results were found for the idea of motivated memory regarding worldviews, future research should not discredit this concept as a valuable point of investigation. Many individuals perceive climate change to be a psychologically distant risk in terms of both time and space (van der Linden, et al., 2015), therefore they are unlikely to make decisions regarding the information as they read it. Examining how different people recall information about climate change after a delay will enable scientists to determine the best methods for communicating uncertainty.

The current thesis demonstrated that experts should take into account various factors when determining the best way to communicate the uncertainty around climate change. Through integrating the knowledge about how single bound probability estimates are evaluated with a focus on motivated reasoning, researchers who use such statements can decide how best to frame them, in order to enact behaviour change from climate change acceptors and sceptics alike.

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6 Appendices table of contents

Appendix A

The consent form and information screen

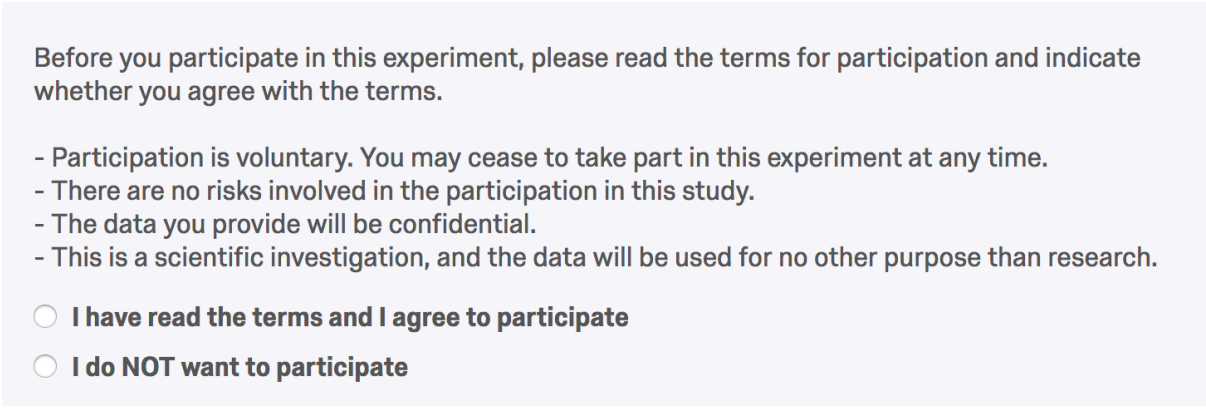


Figure A1. Participant consent form

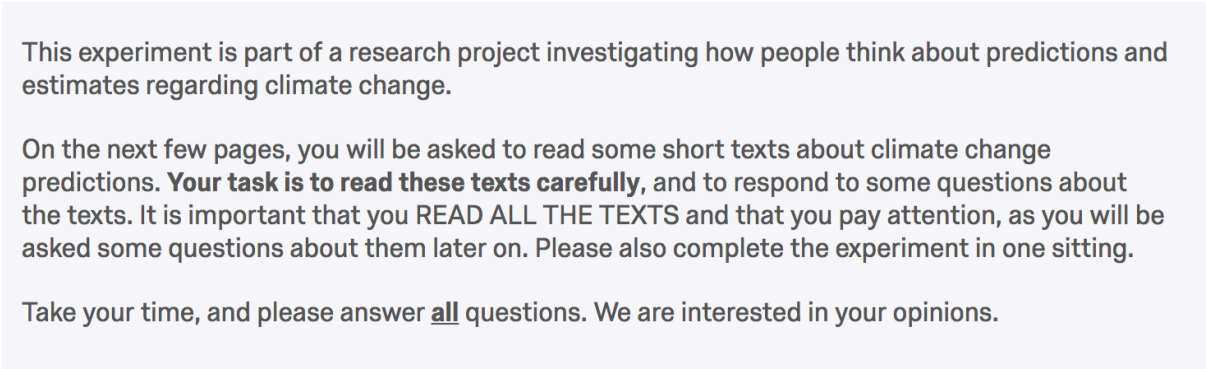


Figure A2. Participant information screen

Appendix B

The photographs used for the picture rating task

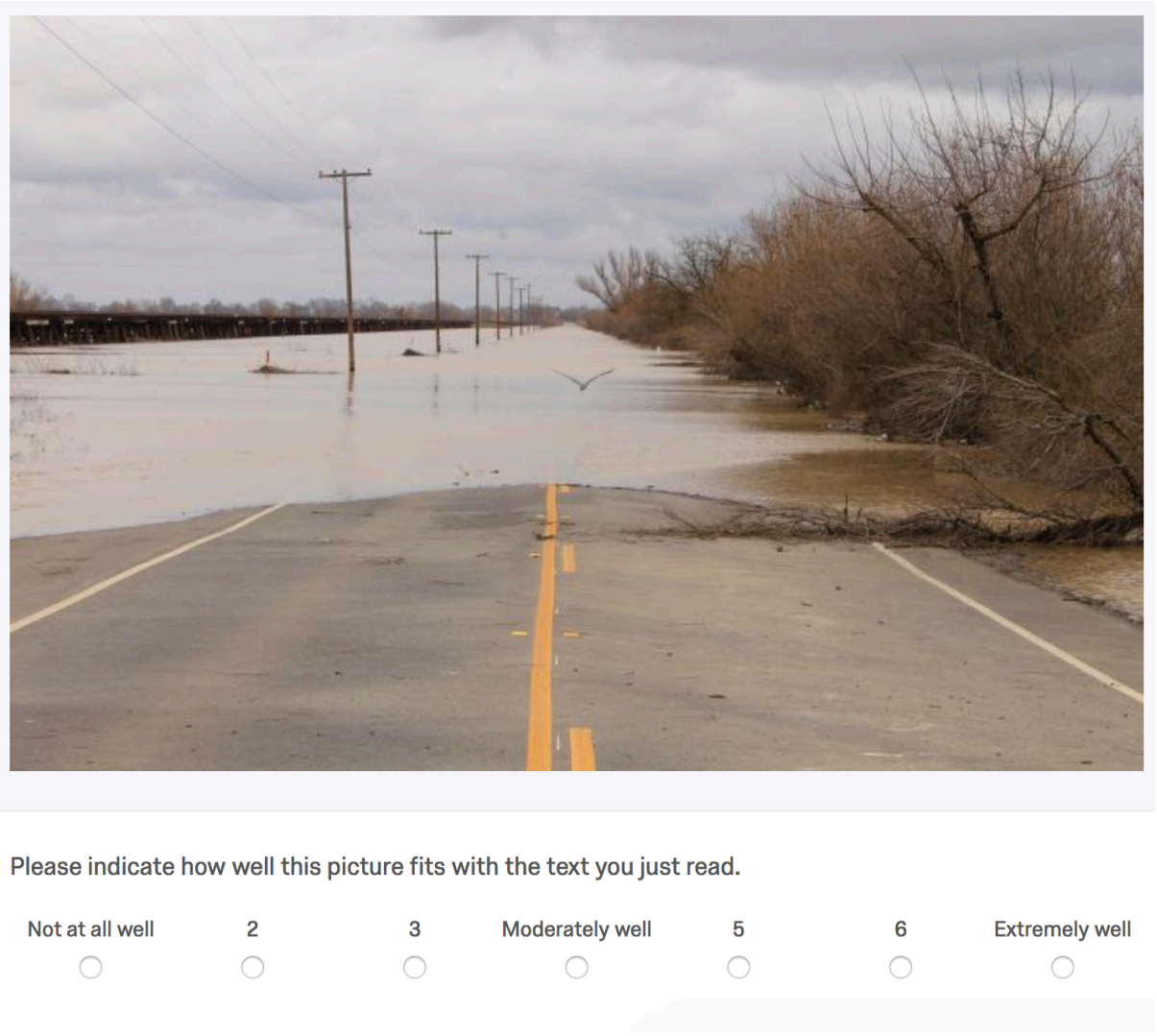


Figure B1. Photograph used for the picture rating task in the sea level scenario, in both Study 1 and 2

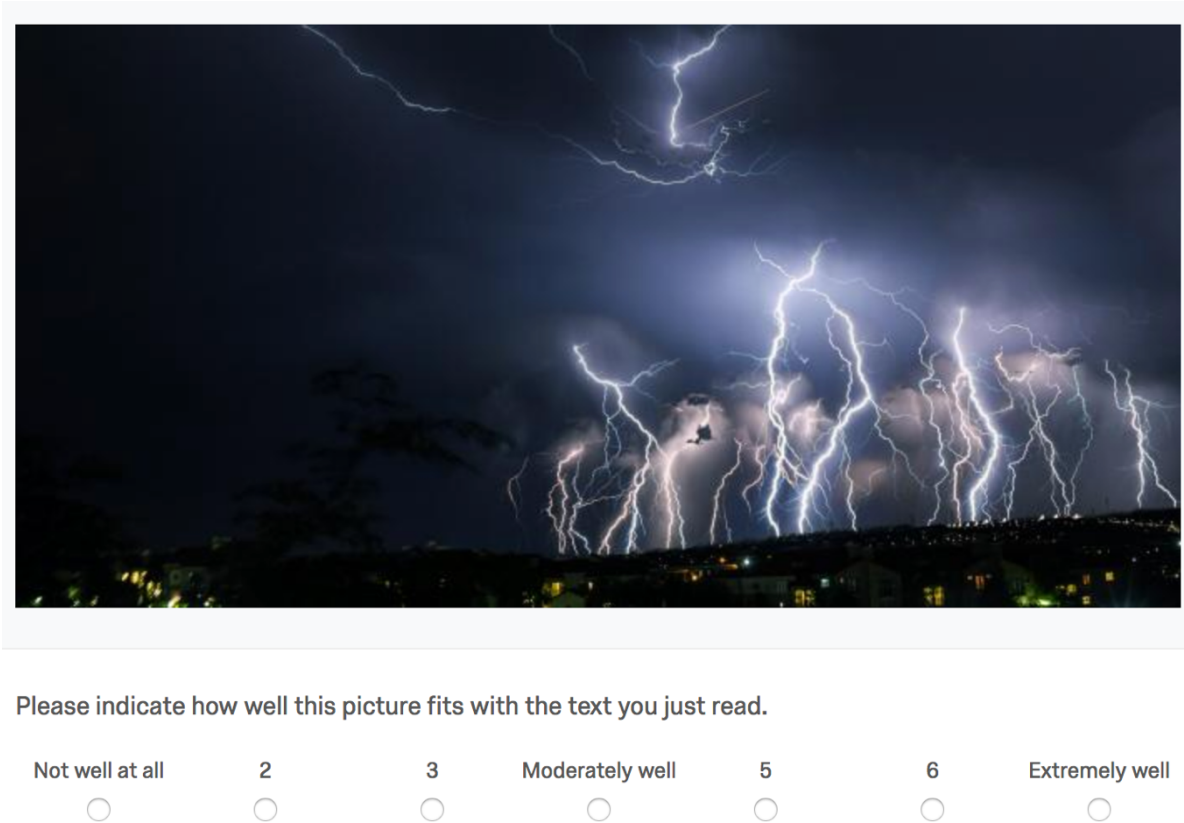


Figure B2. Photograph used for the picture rating task in the lightning scenario, in both Study 1 and 2

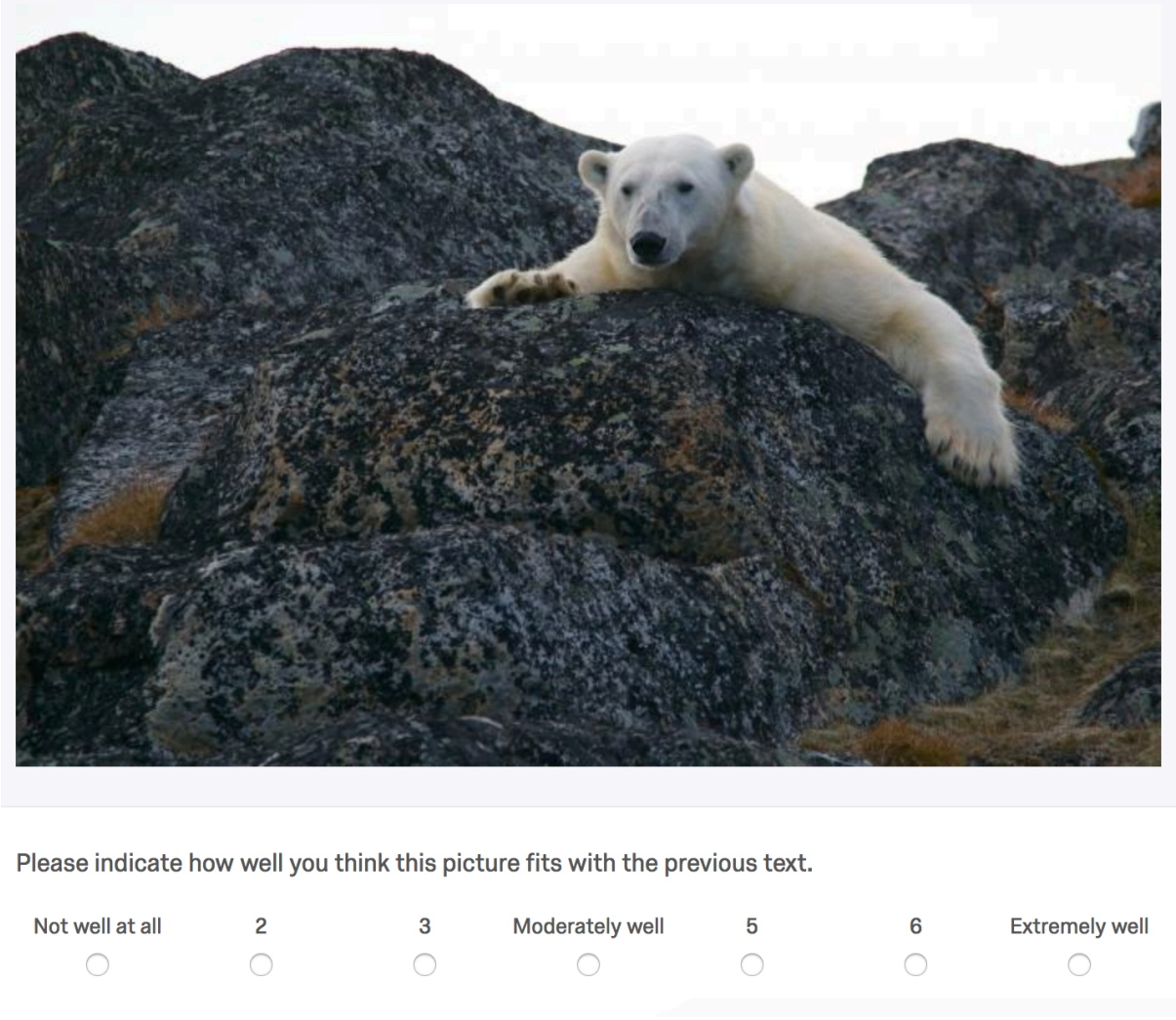


Figure B3. Photograph used for the picture rating task in the polar bear scenario, in both Study 1 and 2

Please indicate how well you think the picture fits with the previous text.

Not at all well	2	3	Moderately well	5	6	Extremely well
○	○	○	○	○	○	○

Figure B4. Photograph used for the picture rating task in the temperature scenario, in both Study 1 and 2

Appendix C

The point and interval scenarios used in Study 1

As global temperatures increase due to climate change, ocean levels are getting higher. Although different climate models give somewhat different predictions, a climate scientist, Dr. Seaworth, concludes we can expect the oceans to rise by 24 inches by 2100, enough to swamp many of the cities along the U.S. East Coast.

Figure C1. Point sea level scenario for Study 1

As global temperatures increase due to climate change, ocean levels are getting higher. Although different climate models give somewhat different predictions, a climate scientist, Dr. Seaworth, concludes we can expect the oceans to rise by 12 to 36 inches by 2100, enough to swamp many of the cities along the U.S. East Coast.

Figure C2. Interval sea level scenario for Study 1

The increase in global temperatures due to climate change may affect weather phenomena such as thunderstorms. In the western United States, temperature rises are expected to lead to an increase in lightning. Based on different climate models, climate scientist, Dr. Donner, states that lightning in the western US will most likely increase by 21% by 2050, causing more frequent and devastating forest fires.

Figure C3. Point lightning scenario for Study 1

The increase in global temperatures due to climate change may affect weather phenomena such as thunderstorms. In the western United States, temperature rises are expected to lead to an increase in lightning. Based on different climate models, climate scientist, Dr. Donner, states that lightning in the western US will most likely increase by 13 to 29% by 2050, causing more frequent and devastating forest fires.

Figure C4. Interval lightning scenario for Study 1

Appendix D

The lower and upper bound scenarios used in Study 1

Climate change has led to an increase in the ice-free period in Hudson Bay (Canada) over the past 20 years. This has cut short polar bears' vital hunting season, which makes life very difficult for the bears. Based on data from several models, a Canadian research group predicts that two thirds of polar bears in this area will become extinct by 2050. Another climate scientist, Dr. North, states that it is more than 60% likely that this prediction will come true.

Figure D1. Lower bound polar bear scenario for Study 1

Climate change has led to an increase in the ice-free period in Hudson Bay (Canada) over the past 20 years. This has cut short polar bears' vital hunting season, which makes life very difficult for the bears. Based on data from several models, a Canadian research group predicts that two thirds of polar bears in this area will become extinct by 2050. Another climate scientist, Dr. North, states that it is less than 60% likely that this prediction will come true.

Figure D2. Upper bound polar bear scenario for Study 1

The global greenhouse gas concentration has increased rapidly the last 200 years, and is expected to continue increasing for several decades. This is a main contributor to increasing global temperatures. Based on different climate models, an Australian research group predicts that the temperature will increase by 5 degrees Fahrenheit by the end of the century. Another climate scientist, Dr. Sommer, states that it is more than 70% likely that this prediction will come true.

Figure D3. Lower bound temperature scenario for Study 1

The global greenhouse gas concentration has increased rapidly the last 200 years, and is expected to continue increasing for several decades. This is a main contributor to increasing global temperatures. Based on different climate models, an Australian research group predicts that the temperature will increase by 5 degrees Fahrenheit by the end of the century. Another climate scientist, Dr. Sommer, states that it is less than 70% likely that this prediction will come true.

Figure D4. Upper bound temperature scenario for Study 1

Appendix E

The Cognition Worldview Scale (CCWS; Kahan, 2012)

Cultural Cognition Worldview Scales (Long & Short Forms)

Order of scales should be rotated and order of items within each scale randomized. Italicized items constitute "short form" versions of each scale.

A. *Group* or *Individualism-Communitarianism* (reverse code "C" items)

People in our society often disagree about how far to let individuals go in making decisions for themselves. How strongly you agree or disagree with each of these statements? [strongly disagree, moderately disagree, slightly disagree, slightly agree, moderately agree, strongly agree]

1. *IINTRSTS. The government interferes far too much in our everyday lives.*
2. *CHARM. Sometimes government needs to make laws that keep people from hurting themselves.*
3. *IPROTECT. It's not the government's business to try to protect people from themselves.*
4. *IPRIVACY. The government should stop telling people how to live their lives.*
5. *CPROTECT. The government should do more to advance society's goals, even if that means limiting the freedom and choices of individuals.*
6. *CLIMCHOI. Government should put limits on the choices individuals can make so they don't get in the way of what's good for society.*
7. INEEDS. Too many people today expect society to do things for them that they should be doing for themselves.
8. CNEEDS. It's society's responsibility to make sure everyone's basic needs are met.
9. INEEDY. It's a mistake to ask society to help every person in need.
10. CRELY. People should be able to rely on the government for help when they need it.
11. IRESPON. Society works best when it lets individuals take responsibility for their own lives without telling them what to do.
12. ITRIES. Our government tries to do too many things for too many people. We should just let people take care of themselves.
13. IFIX. If the government spent less time trying to fix everyone's problems, we'd all be a lot better off.
14. IENJOY. People who are successful in business have a right to enjoy their wealth as they see fit.
15. IMKT. Free markets--not government programs--are the best way to supply people with the things they need.
16. IPROFIT. Private profit is the main motive for hard work.
17. IGOVWAST. Government regulations are almost always a waste of everyone's time and money.

Figure E1. Questions pertaining to Group on the CCWS

B. *Grid* or *Hierarchy-Egalitarianism* (reverse code "E" items)

People in our society often disagree about issues of equality and discrimination. How strongly you agree or disagree with each of these statements? [strongly disagree, moderately disagree, slightly disagree, slightly agree, moderately agree, strongly agree]

1. *HEQUAL. We have gone too far in pushing equal rights in this country.*
2. HREVDIS1. Nowadays it seems like there is just as much discrimination against whites as there is against blacks.
3. *EWEALTH. Our society would be better off if the distribution of wealth was more equal.*
4. *ERADEQ. We need to dramatically reduce inequalities between the rich and the poor, whites and people of color, and men and women.*
5. *EDISCRIM. Discrimination against minorities is still a very serious problem in our society.*
6. *HREVDIS2. It seems like blacks, women, homosexuals and other groups don't want equal rights, they want special rights just for them.*
7. HCHEATS. It seems like the criminals and welfare cheats get all the breaks, while the average citizen picks up the tab.
8. EDIVERS. It's old-fashioned and wrong to think that one culture's set of values is better than any other culture's way of seeing the world.
9. HWMNRTS. The women's rights movement has gone too far.
10. ESEXIST. We live in a sexist society that that is fundamentally set up to discriminate against women.
11. HTRADFAM. A lot of problems in our society today come from the decline in the traditional family, where the man works and the woman stays home.
12. *HFEMININ. Society as a whole has become too soft and feminine.*
13. EROUGH. Parents should encourage young boys to be more sensitive and less rough and tough.

Figure E2. Questions pertaining to Grid on the CCWS

Appendix F

The questions used to assess participants' views about climate change, taken from Heath and Gifford (2006)

Perception that global climate change is occurring:

1. How likely do you think it is that global warming is occurring now?
   very unlikely unlikely unsure likely very likely
2. I have already noticed some signs of global warming.
   strongly disagree disagree unsure agree strongly agree
3. It seems to me that temperature is warmer now than in years before.
   Strongly disagree disagree unsure agree strongly agree
4. It seems to me that weather patterns have changed compared to when I was a child.
   strongly disagree disagree unsure agree strongly agree
5. I am quite sure that global warming is occurring now.
   strongly disagree disagree unsure agree strongly agree
6. The following is an actual newspaper article reported last year:

Figure F1. Questions assessing belief that climate change is occurring

Perception of causes:

(The response format for all of the items below is the same: strongly agree to strongly disagree.)

1. Global warming is mainly due to natural causes, not human activity.
2. The main causes of global warming are human activities.
3. Global warming is merely a natural fluctuation, not caused by human activity.
4. I am quite sure that human activities are to be blamed for global warming.

Figure F2. Questions assessing perceptions of the causes of climate change

Perception of consequences:

1. Unlike what most scientists say, there will be some positive consequences of global warming for the environment.
2. The consequences of global warming will be harmful for the environment.
3. Global warming will bring about some serious negative consequences.
4. The consequences of global warming will be more positive than negative overall.

Figure F3. Questions assessing perceptions of the consequences of climate change

Appendix G

Evaluation questions used in Study 1

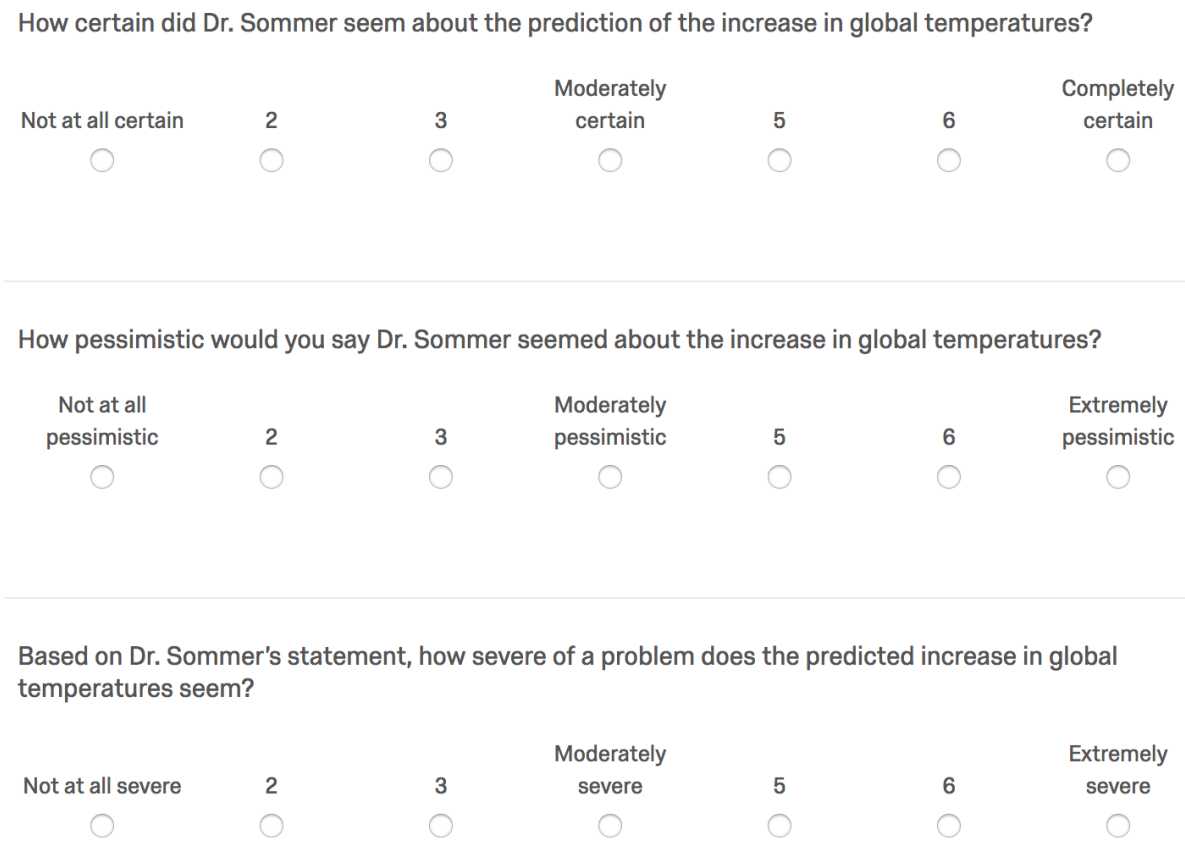


Figure G1. Evaluation questions for the sea level scenario in Study 1

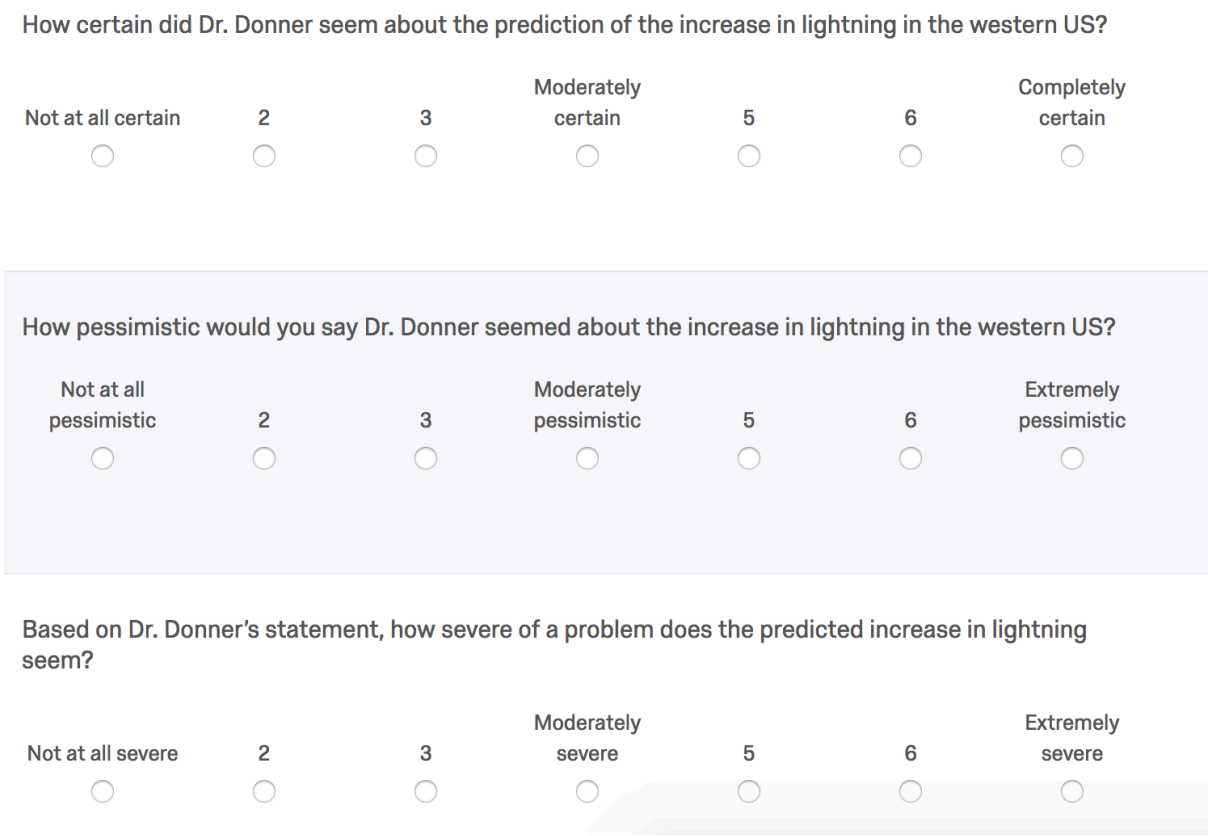


Figure G2. Evaluation questions for the lightning scenario in Study 1

Figure G3. Evaluation questions for the polar bear scenario in Study 1

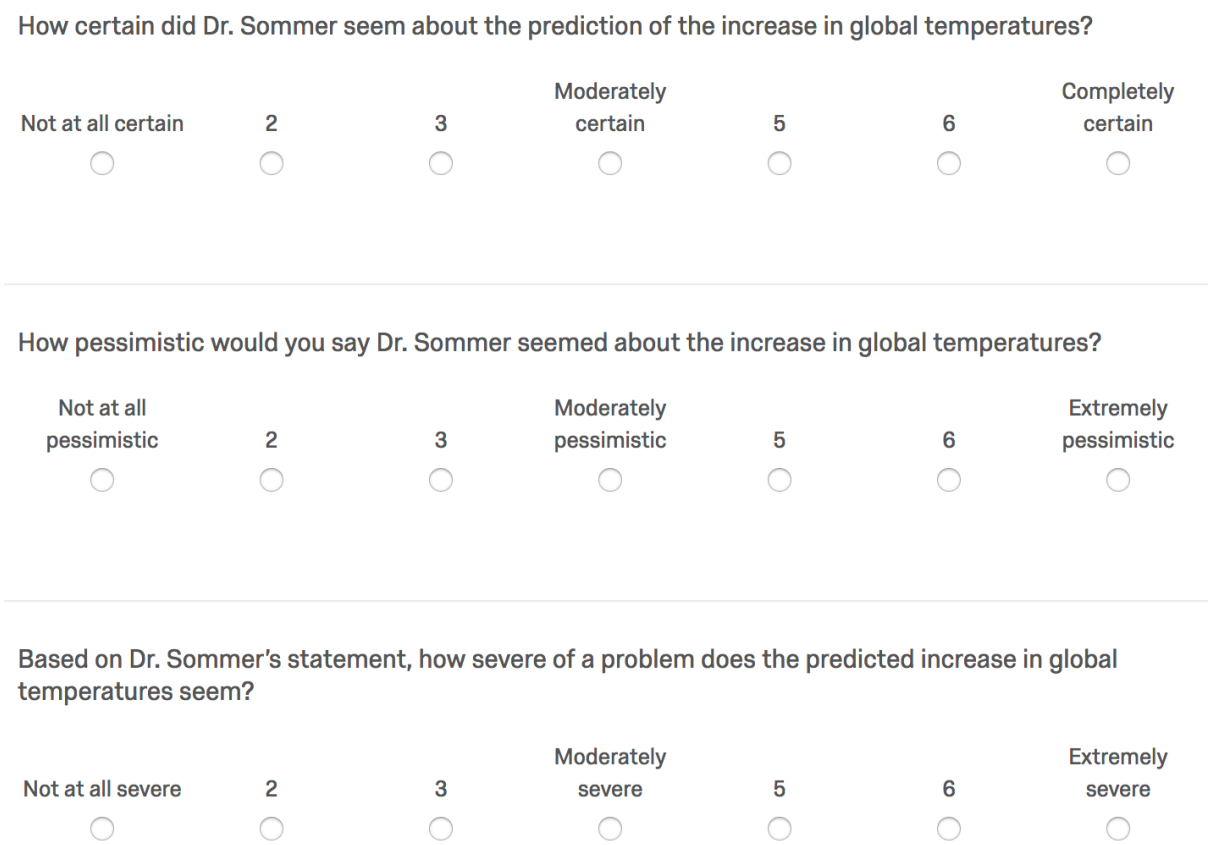


Figure G4. Evaluation questions for the temperature scenario in Study 1

Appendix H

Free-recall task for all scenarios used in both Study 1 and 2

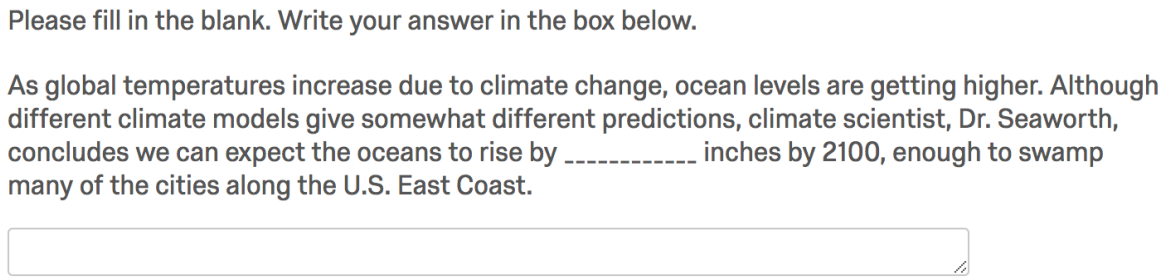


Figure H1. Free-recall questions for the sea level scenario, utilised in both Study 1 and 2

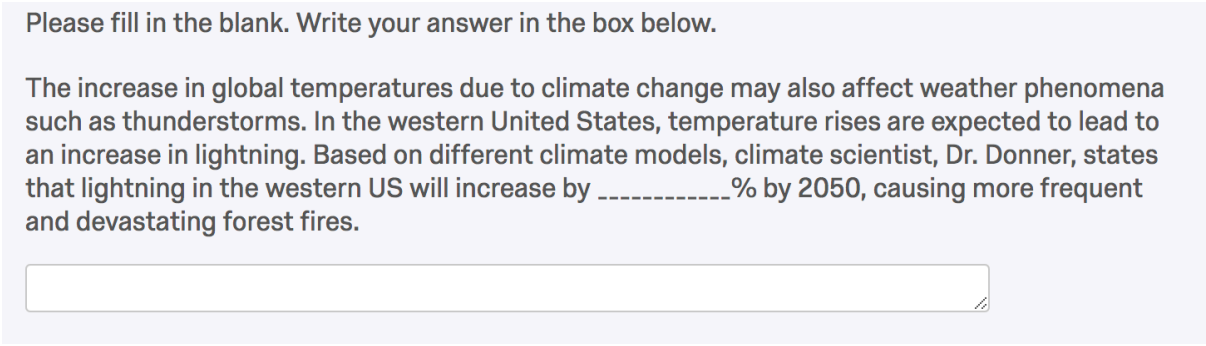
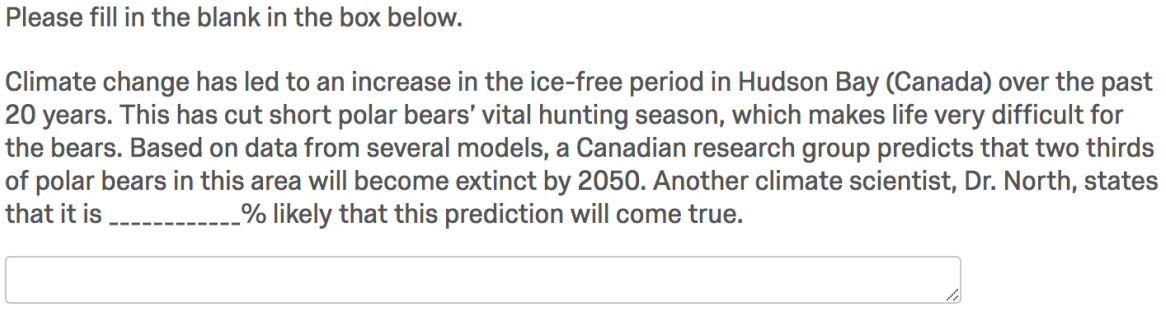


Figure H2. Free-recall questions for the lightning scenario, utilised in both Study 1 and 2

Figure H3. Free-recall questions for the polar bear scenario, utilised in both Study 1 and 2



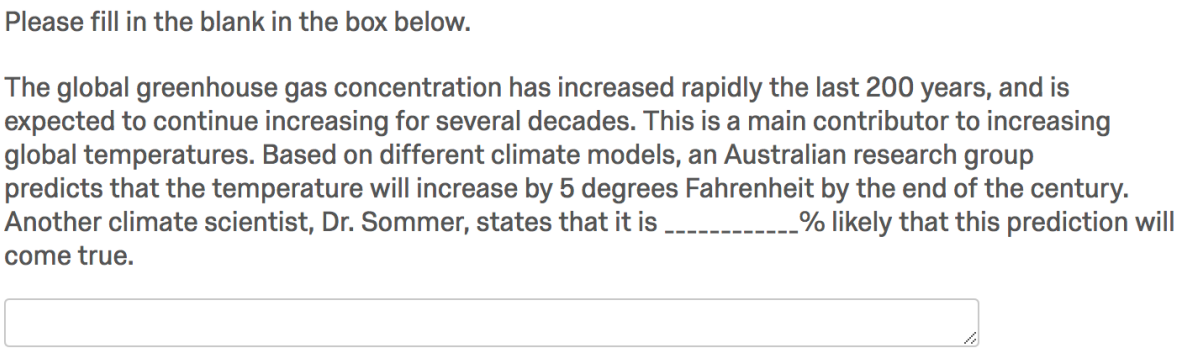


Figure H4. Free-recall questions for the temperature scenario, utilised in both Study 1 and 2

Appendix I

Debrief screen shown to participants

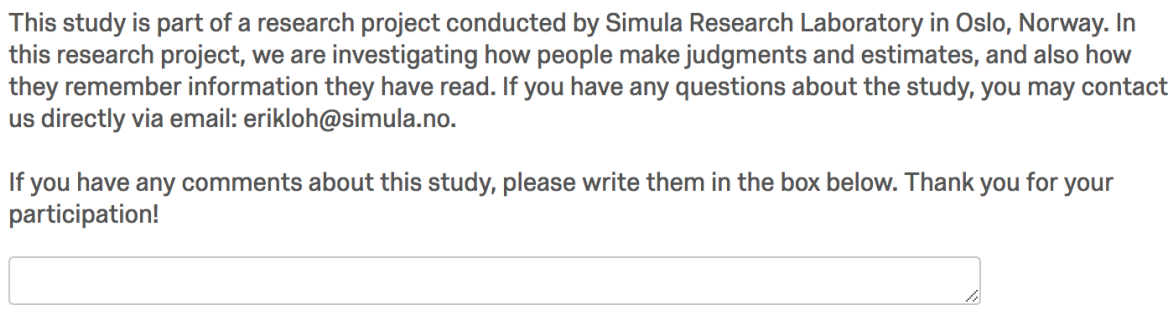


Figure I1. Debrief screen shown to participants in both Study 1 and 2

Appendix J

The wide and narrow interval scenarios used in Study 2

As global temperatures increase due to climate change, ocean levels are getting higher. Although different climate models give somewhat different predictions, a climate scientist, Dr. Seaworth, concludes we can expect the oceans to rise by 4 to 39 inches by 2100. This may have negative consequences for coastal cities both in the U.S. and abroad.

Figure J1. Wide interval sea level scenario in Study 2

As global temperatures increase due to climate change, ocean levels are getting higher. Although different climate models give somewhat different predictions, a climate scientist, Dr. Seaworth, concludes we can expect the oceans to rise by 18 to 25 inches by 2100. This may have negative consequences for coastal cities both in the U.S. and abroad.

Figure J2. Narrow interval sea level scenario in Study 2

The increase in global temperatures due to climate change may affect weather phenomena such as thunderstorms. In the western United States, temperature rises are expected to lead to an increase in lightning. Based on different climate models, climate scientist, Dr. Donner, states that lightning in the western US will most likely increase by 6 to 49% by 2050, causing more frequent and devastating forest fires.

Figure J3. Wide interval lightning scenario in Study 2

The increase in global temperatures due to climate change may affect weather phenomena such as thunderstorms. In the western United States, temperature rises are expected to lead to an increase in lightning. Based on different climate models, a climate scientist, Dr. Donner, states that lightning in the western US will most likely increase by 23 to 31% by 2050, causing more frequent and devastating forest fires.

Figure J4. Narrow interval lighting scenario in Study 2

Appendix K

The lower and upper bound scenarios used in Study 2

Climate change has led to an increase in the ice-free period in Hudson Bay (Canada) over the past 20 years. This has cut short polar bears' vital hunting season, which makes life very difficult for the bears. Based on data from several models, a Canadian research group predicts that two thirds of polar bears in this area will become extinct by 2050. Another climate scientist, Dr. North, states that it is more than 70% likely that this prediction will come true.

Figure K1. Lower bound polar bear scenario in Study 2

Climate change has led to an increase in the ice-free period in Hudson Bay (Canada) over the past 20 years. This has cut short polar bears' vital hunting season, which makes life very difficult for the bears. Based on data from several models, a Canadian research group predicts that two thirds of polar bears in this area will become extinct by 2050. Another climate scientist, Dr. North, states that it is less than 70% likely that this prediction will come true.

Figure K2. Upper bound polar bear scenario in Study 2

The global greenhouse gas concentration has increased rapidly the last 200 years, and is expected to continue increasing for several decades. This is a main contributor to increasing global temperatures. Based on different climate models, an Australian research group predicts that the temperature will increase by 5 degrees Fahrenheit by the end of the century. Another climate scientist, Dr. Sommer, states that it is more than 40% likely that this prediction will come true.

Figure K3. Lower bound temperature scenario in Study 2

The global greenhouse gas concentration has increased rapidly the last 200 years, and is expected to continue increasing for several decades. This is a main contributor to increasing global temperatures. Based on different climate models, an Australian research group predicts that the temperature will increase by 5 degrees Fahrenheit by the end of the century. Another climate scientist, Dr. Sommer, states that it is less than 40% likely that this prediction will come true.

Figure K4. Upper bound temperature scenario in Study 2

Appendix L

Evaluation questions used in Study 2

Please think back to the text you read about **sea level rise** and the statement that Dr. Seaworth made. To what extent do you agree/ disagree with the following statements:

	Strongly Disagree	2	3	Moderately agree	5	6	Strongly Agree
It seems as though Dr. Seaworth is exaggerating the figures	○	○	○	○	○	○	○
Dr. Seaworth seems to be sure about what will happen	○	○	○	○	○	○	○
Dr. Seaworth's estimate demonstrates just how bad things could get	○	○	○	○	○	○	○
Dr. Seaworth's estimate shows that the consequences of climate change might not be so severe	○	○	○	○	○	○	○
It seems like Dr. Seaworth does not know what will happen to the sea level	○	○	○	○	○	○	○
It seems that Dr. Seaworth has made a bold and risky prediction	○	○	○	○	○	○	○

Figure L1. Evaluation questions for the sea level scenario in Study 2

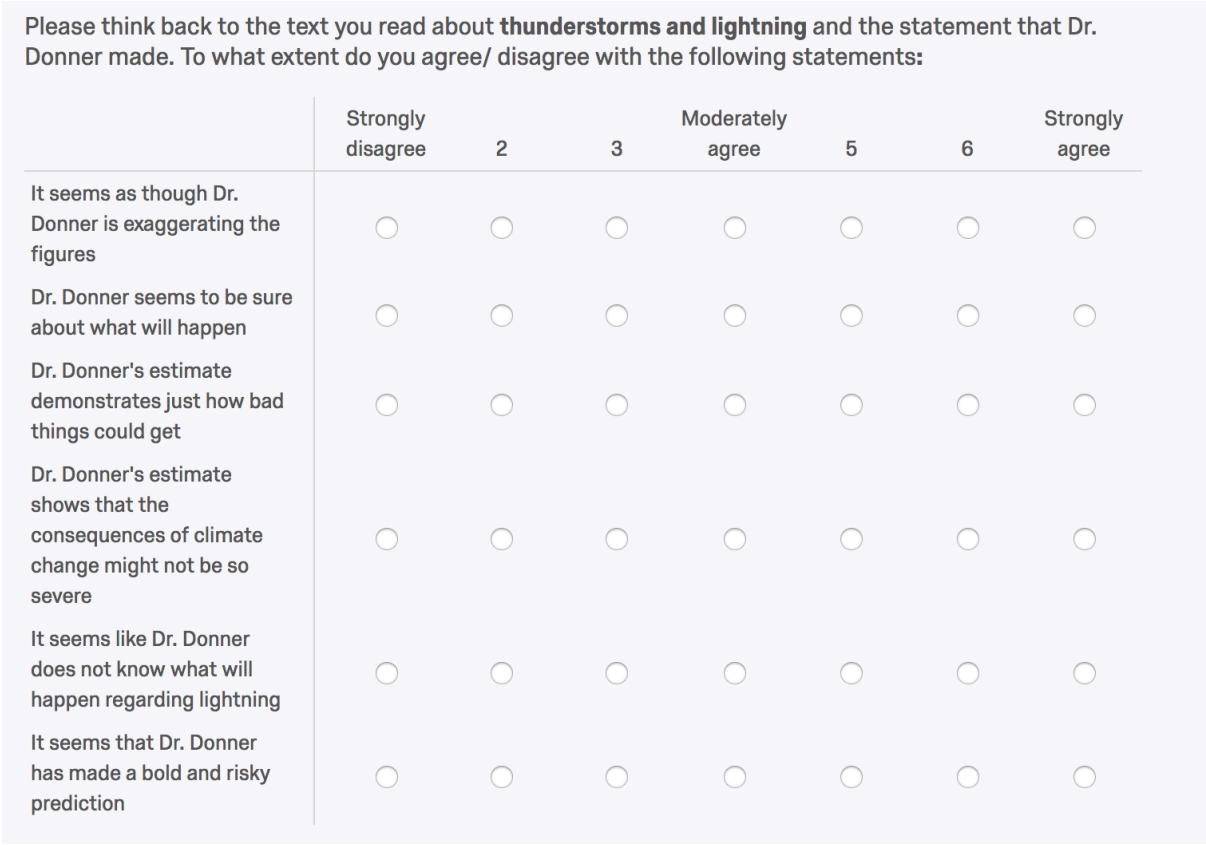


Figure L2. Evaluation questions for the lightning scenario in Study 2

Please think back to the text you read about **polar bears** and the statement that Dr. North made. To what extent do you agree/ disagree with the following statements:

	Strongly disagree	2	3	Moderately agree	5	6	Strongly agree
It seems as though Dr. North is exaggerating the figures	○	○	○	○	○	○	○
Dr. North seems to be sure about what will happen	○	○	○	○	○	○	○
Dr. North's estimate demonstrates just how bad things could get	○	○	○	○	○	○	○
Dr. North's estimate shows that the consequences of climate change might not be so severe	○	○	○	○	○	○	○
It seems like Dr. North does not know what will happen to the polar bears	○	○	○	○	○	○	○
It seems that Dr. North has made a bold and risky prediction	○	○	○	○	○	○	○

Figure L3. Evaluation questions for the polar bear scenario in Study 2

Please think back to the text you read about **global temperatures** and the statement that Dr. Sommer made. To what extent do you agree/ disagree with the following statements:

	Strongly disagree	2	3	Moderately agree	5	6	Strongly agree
It seems as though Dr. Sommer is exaggerating the figures	○	○	○	○	○	○	○
Dr. Sommer seems to be sure about what will happen	○	○	○	○	○	○	○
Dr. Sommer's estimate demonstrates just how bad things could get	○	○	○	○	○	○	○
Dr. Sommer's estimate shows that the consequences of climate change might not be so severe	○	○	○	○	○	○	○
It seems like Dr. Sommer does not know what will happen to the global temperature	○	○	○	○	○	○	○
It seems that Dr. Sommer has made a bold and risky prediction	○	○	○	○	○	○	○

Figure L4. Evaluation questions for the temperature scenario in Study 2

Appendix M

The recognition task used in Study 2

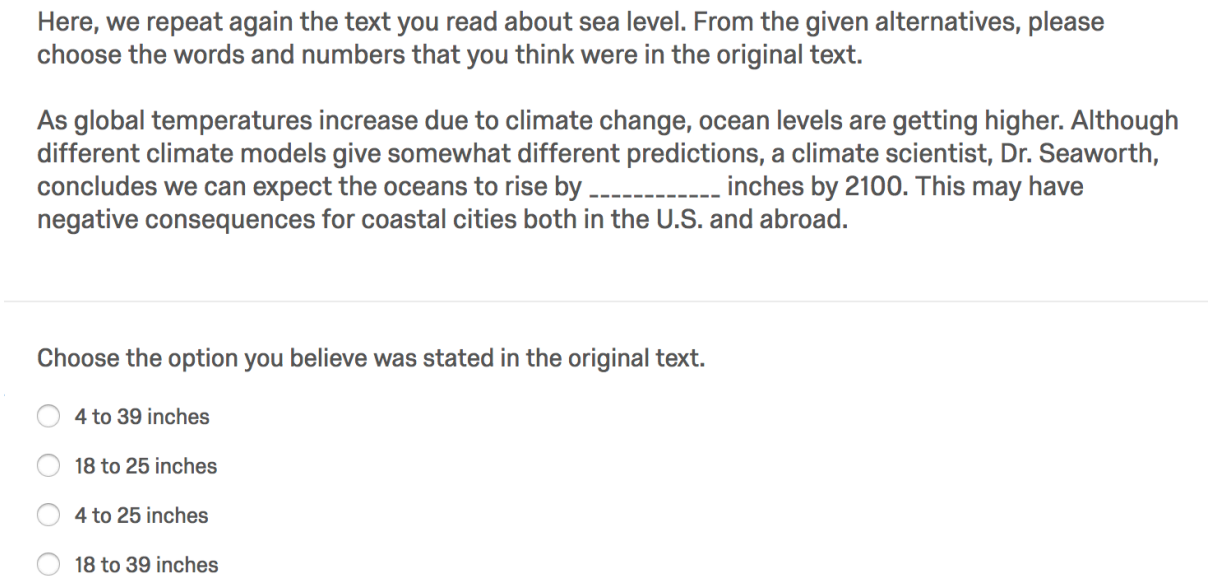


Figure M1. Recognition task for the sea level scenario in Study 2

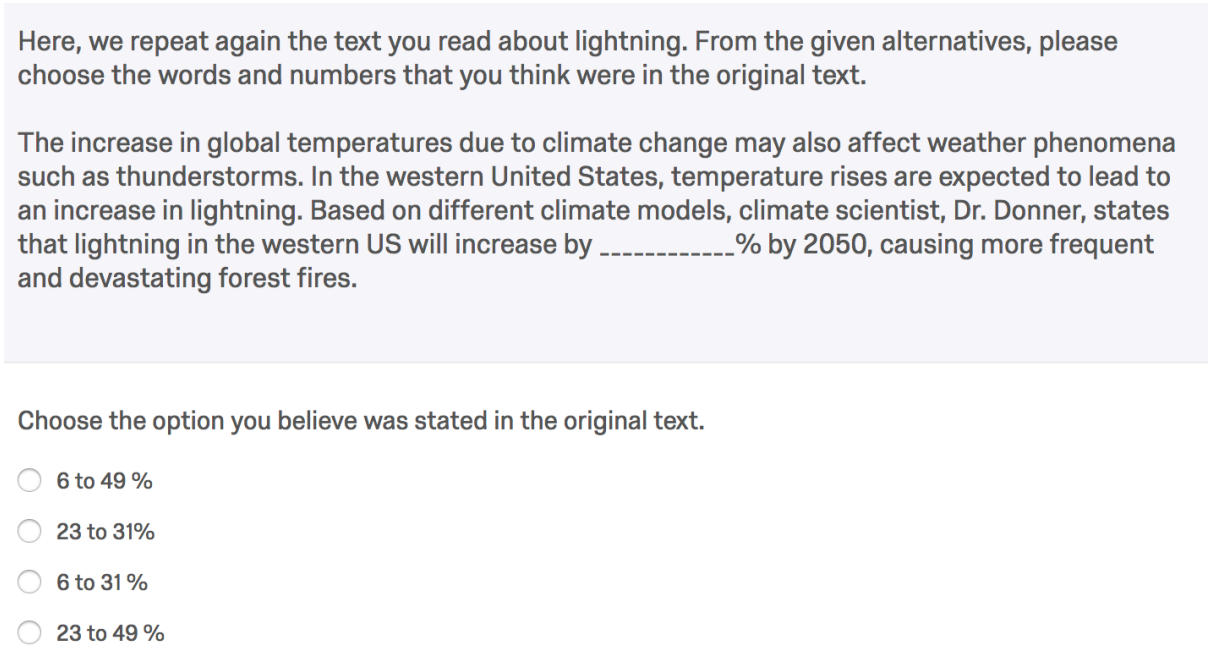


Figure M2. Recognition task for the lightning scenario in Study 2

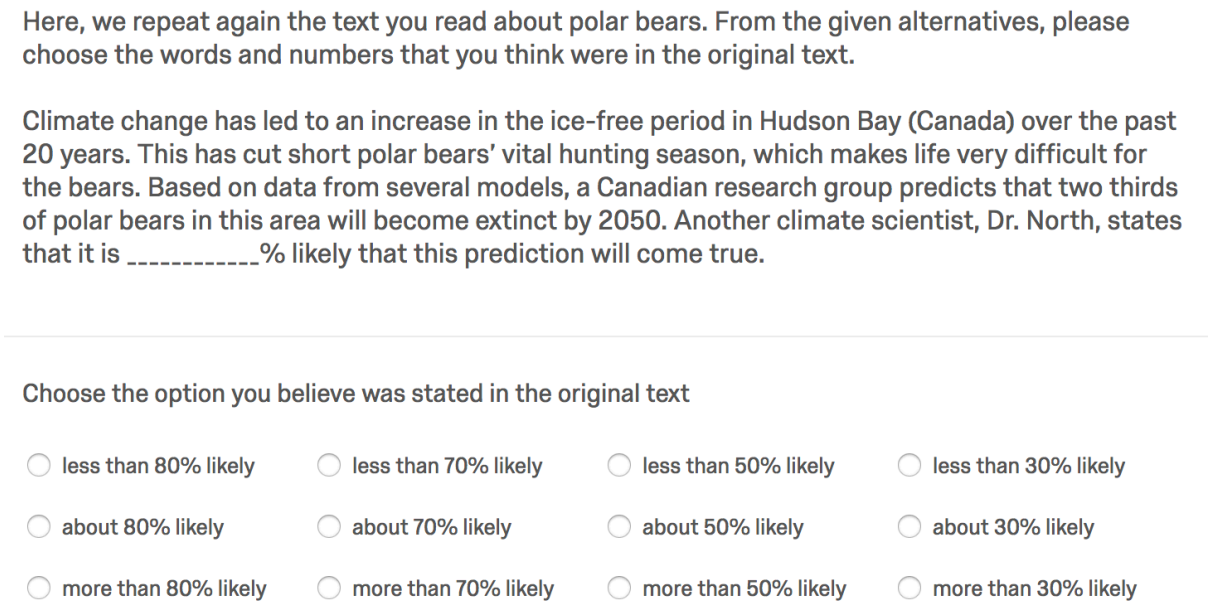


Figure M3. Recognition task for the polar bear scenario in Study 2

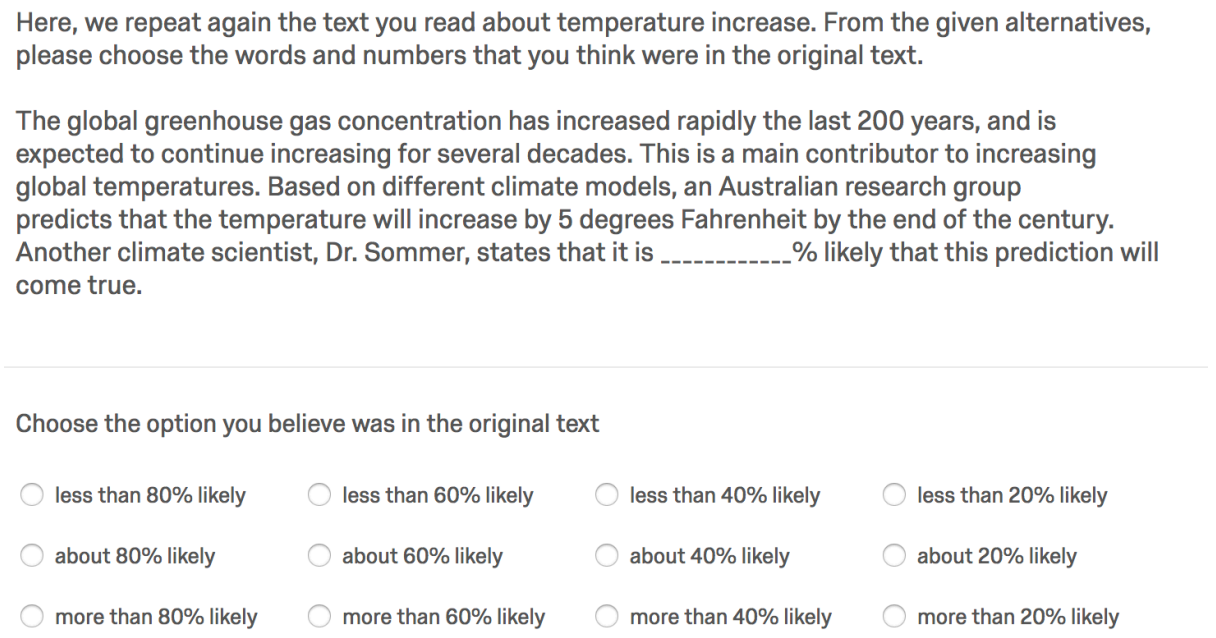


Figure M4. Recognition task for the temperature scenario in Study 2