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Communicating Uncertain Climate Futures: Lessons From the Literature

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ABSTRACT

There is increasing demand for information about future climate risk to inform climate change adaptation planning. However, climate change impacts are uncertain and complex, and climate information is often technical and challenging to communicate. To inform effective methods for communicating future climate information, we undertake a review of reviews of risk communication literature, with a focus on improving comprehension. We do not constrain our literature search by the type of risk or the geographical region to allow for interdisciplinary and geographical learning, but find that most reviews occur within health, and there is a bias towards North American and European studies. Four key themes were identified during the review: (1) understanding probability and uncertainty, (2) presentation of risk and probability information, (3) positive or negative framing of risk information, and (4) the process of risk communication. Understanding of probabilistic and uncertain information varies amongst not only the general public but also scientific experts, possibly due to differences in cognitive processes and familiarity with statistics. Icon arrays and bar charts were identified as improving comprehension of risk information, whilst qualitative descriptors of risk were deemed less effective than quantitative descriptions, though a combination of the two may be most optimal. Common methods of communicating climate projections (box plots and plume plots) have not been widely reviewed. Health risks have different characteristics from climate change risks and as such we identify lessons that are relevant to climate, and areas where further research is needed to inform effective climate risk communication.

This article is categorized under:

Perceptions, Behavior, and Communication of Climate Change > Communication

The Social Status of Climate Change Knowledge > Knowledge and Practice

1 | Introduction

There are increasing efforts by countries, companies and individuals to adapt to the changing climate. Although climate services have made progress in building shared understanding of climate risks between climate experts and decision-makers (Steynor et al. 2016), communicating about future climate remains a challenge. It can be difficult for decision-makers to understand how climate change might affect their context and, due to the complex nature of climate adaptation, there are many

factors beyond climate influencing decision-making, as well as factors such as the local economy and technological development that interact with climate (Tall et al. 2018). While there is unequivocal evidence about climate change at a global scale, there are large uncertainties in how global warming will affect regional and local scale climate (James et al. 2014; Shepherd 2014). Innovative approaches are applied within the field of climate services to communicate uncertain climate futures, but the efficacy of these approaches is not often assessed systematically. Meanwhile, there is great potential to learn from risk communication research in other domains that have systematically assessed the efficacy of communicating risks. This review of reviews brings together empirical research findings and recommendations from across the broader field of risk communication to identify conclusions that are relevant for communicating uncertain climate change. We focus specifically on comprehension of information, noting that comprehension of future climate risk is a necessary but by no means a sufficient condition for effective adaptation decisions.

Insights from the broader field of risk communication have the potential to be of considerable use for informing climate change communications. The goals of risk communication can vary, but usually include promoting or influencing comprehension, perception, preference, behavior, and/or informed decision making. While the broader topic of climate risk perception has been widely studied (Conway 2024; Pidgeon 2012; Salas Reyes et al. 2021), existing research has largely focused on beliefs and concerns about climate change, with fewer studies directly addressing the challenge of improving comprehension of future climate information. Additionally, there is a wealth of literature in environmental psychology, which has identified important lessons for communicating climate change to promote sustainable mitigation behaviors (Steg et al. 2012). While this latter body of work provides valuable insights for communicating in an adaptation context, it does not always focus on the specific challenges of communicating technical, quantitative, and uncertain information to inform decision-making.

An understanding of climate projections and risks is required for an individual to access and evaluate future information, process the meaning of risk estimates and to make informed decisions (Pidgeon and Fischhoff 2011). Failure to consider the uncertainties inherent in climate projections can result in poor understanding of this information, or even maladaptation (Schipper 2020). Studies that have investigated comprehension of climate projections indicate that preference for specific communication formats does not always translate into better comprehension (Lorenz et al. 2015) and may in some cases result in overconfidence in understanding (Daron et al. 2015). Meanwhile, mapping climate model data in slightly different ways can lead to large differences in interpretations of precipitation change (Daron et al. 2021), highlighting the need for further research to better understand appropriate ways of visualizing risk information.

Just as climate information users require information that is understandable, professionals working in climate science need guidance on how to communicate uncertain climate futures. Intergovernmental Panel on Climate Change (IPCC) authors have called for guidance on visual communications and communicating probabilistic information (Janzwood 2020). Meanwhile a review of climate information websites found that the websites required a high level of technical capability and that those developing the websites overestimated how easy they were to use (Hewitson et al. 2017). Indeed, climate scientists' extensive familiarity with their area of expertise may hinder their ability to communicate information to non-specialists, due to the disparity in experts' and users' considerations of what is easy to understand (Pidgeon and Fischhoff 2011; Porter and Dessai 2017).

Based on existing empirical risk communications research, we investigate (1) what communication methods improve comprehension of risks and (2) how relevant these broader risks communication findings are to improving understanding of future climate change information? We undertake a review of reviews to synthesize the vast amount of existing risk communications literature to establish a consensus among findings and reflect on the relevance to climate change communications. This manuscript is structured with a review methodology, followed by the literature trends in the identified review papers. A results section with four themes is discussed before the relevance of the findings to future climate information and risks is presented. The paper concludes with suggestions for future research and conclusions.

2 | Methodology

A systematic search and review of reviews of peer-reviewed journal articles was undertaken (Grant and Booth 2009) with a focus on the risk communications findings and frameworks in the context of improving comprehension, understanding or interpretation. Comprehension is an individual's ability to understand a concept or action and relies on a higher cognitive process that also relies on existing knowledge to make relations between concepts (Wang and Gafurov 2003). While communication, understanding or interpretation are uniquely defined, we use them interchangeably depending on the terminology used in the studies being reviewed. As such the search strings were "(probabilit* OR uncertain* OR futur* OR Africa*) AND ("meta-analysis" OR "meta-analysis" OR "systematic review" OR "thematic review" OR "qualitative review") AND (understand* OR knowledge OR interpret* OR comprehen* OR decision) AND ("risk communication") NOT (child*) NOT (disability OR disabled) NOT ("mental* ill*") NOT (addict*) NOT (dementia)."

Projections of climate to 2050 and 2100 can be difficult to interpret and use in a decision context due to the uncertainties and probabilistic nature of projections. As such, literature that is focused on communicating in uncertain contexts was included in the search, alongside a specific search for African studies. Previous research has primarily focused on Western, Educated, Industrialized, Rich and Democratic (WEIRD) societies (Newson et al. 2018) leaving a gap in studies focused on much of the African context. Climate services in Africa are rapidly developing, alongside the already vast research and actions in climate adaptation and climate-resilient development (Vincent et al. 2020; Vogel et al. 2019), and research on the best methods to communicate future climate information may assist in this effort.

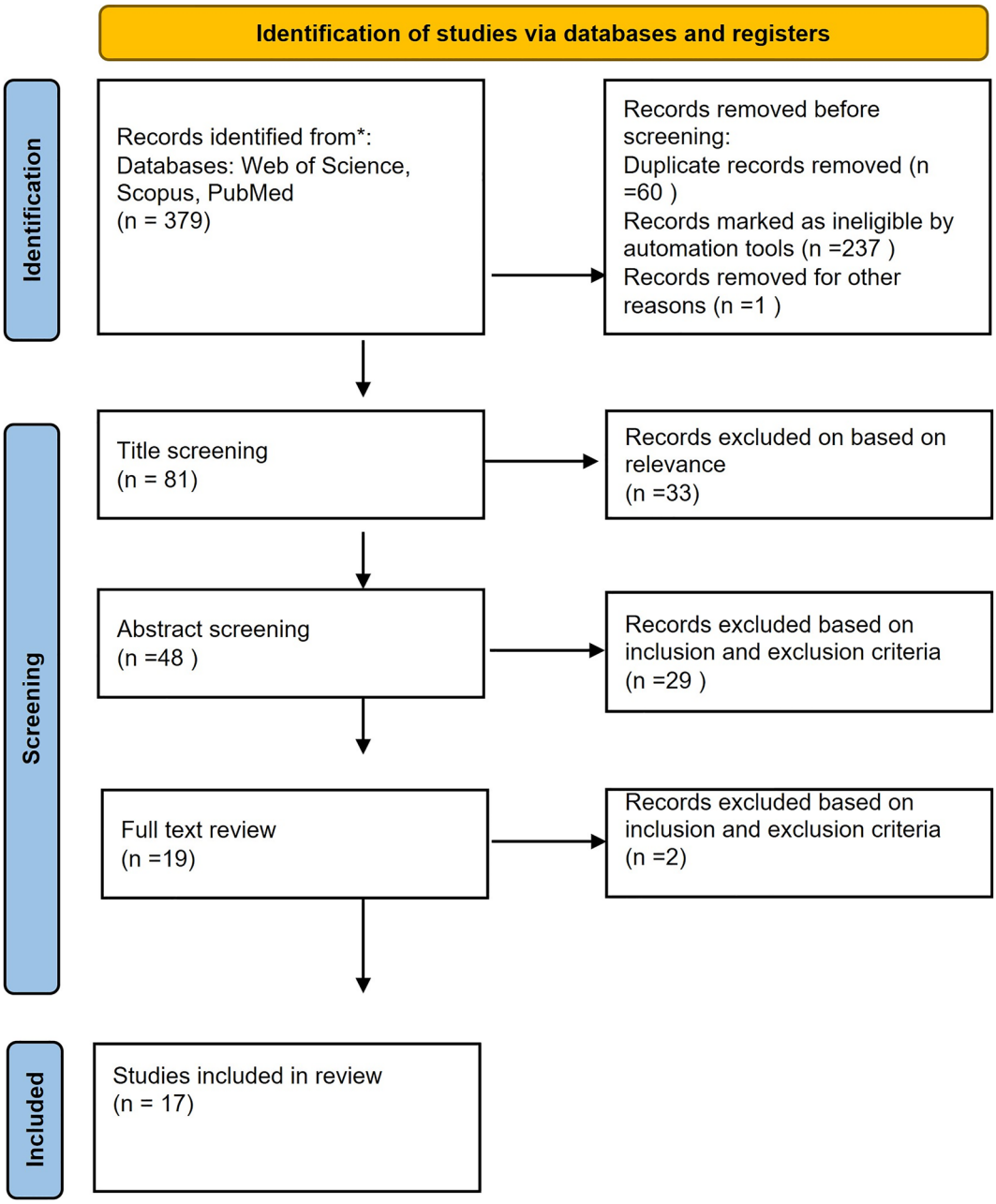


FIGURE 1 | PRISM search flow chart adapted from Moher et al. (2009).

An adapted PRISM search flow chart (Moher et al. 2009) was used to guide the review using three stages: identification, screening, and eligibility (Figure 1). Peer-reviewed journals were identified using three databases: Web of Science, Scopus, and PubMed. The two-stage screening phase included screening the title and then the abstract and was guided by inclusion and exclusion criteria. To be included in the review, papers had to be: focused on improving understanding, interpretation or comprehension of a risk; available in full text; written in English; be a systematic, qualitative, meta or thematic review; and include adult participants. Review papers were excluded if they had included review papers in their review, as this would have resulted in a review of reviews. Additionally review papers that included child participants; participants specifically living with mental illness or physical and/or mental disabilities were not deemed to be the relevant context and tended not to provide findings on uncertainty communication that are potentially generalizable to the context of climate communication. There were no limitations on the year papers were published nor the study design or risks being researched. This was to allow cross-disciplinary learning across fields with various risks and diverse methodological approaches.

The abstract screening was carried out independently by two researchers who then compared their decisions and discussed any variation in the decisions. The inter-rater reliability was measured using Cohen's kappa coefficient, which measured at 0.43 (fair agreement). During the full text screening, two papers were removed as they were not relevant. Specifically, one included a systematic review in their study and the other was not focused on understanding. The systematic review was not preregistered; however, the search strategy and codes for

each database are available for replication in the Supporting Information.

Papers were analyzed using a narrative synthesis using textual descriptions and tabulation (Rodgers et al. 2009). During the analysis, all the papers were read, notes were taken about the papers and information linked was entered in a table. Information in the table included: journal; authors; first author country; first author's institution; review method; databases used for search; geographical focus; years included in the review; number of studies included; methodology type; participant group; risk; use of a theoretical or conceptual framework; main objective; main outcome summary of findings; research suggestions; intervention; exclusion criteria; inclusion criteria; effect size; and effect size method (Table S1). The paper is ordered by the study designs that were included in the review: RCT, RCT and non-RCT, quantitative and mixed method (Table 1). Due to the study design heterogeneity, meta-analysis could not be conducted; instead, a narrative summary of papers occurs in each of the four identified themes using a thematic analysis of the objectives and summary of findings, before an overall summary of findings is provided (Rodgers et al. 2009).

3 | Results

This section will outline the literature characteristics from the 17 papers included in this review of reviews, before providing the results of the findings from the papers which are presented by themes.

3.1 | Literature Characteristics

The 17 review papers included in this review of reviews were published between 2000 and 2023; meanwhile, the review papers reviewed studies that were published from 1966 to 2020. The lead authors were based in the United States ($n=7$) and Europe ($n=10$). The review papers were published in an array of journals (Table S1), but the most common were health or medical journals ($n=10$). As such, most of the papers were also focused on health risks ($n=12$). A mixture of risks was included by two papers, with one including weather, disaster, and health risks (Ripberger et al. 2022) and another including technology, disaster, and health risks (Boase et al. 2017). Other risks included flood, environmental health, and broad emergency public health. Therefore, even in papers that were not concretely focused on health risks, there was an element of health in the risks which highlights the tendency towards health when considering risks. The geographic coverage of the studies included in the reviews was not outlined by 10 of the papers. Of the seven reviews that did outline the coverage, the reviews included studies from North America ($n=7$), Europe ($n=6$), Asia ($n=4$), Oceania ($n=4$) Central and South America ($n=2$), and Africa ($n=2$). However, within the studies there was a bias towards Europe and North America. For example, although Boyd and Furgal's (2019) review included studies from North America, Asia and Central America, seven studies covered the United States and five studies focused on Canada; meanwhile Guatemala, India, and Bolivia were represented by only one study each. As such, the research in this review is skewed towards North America and Europe, and as such does not well represent other regions.

Systematic reviews were conducted by most papers ($n=16$) with only one paper presenting a scoping review. A rapid narrative review was conducted alongside a systematic review in one paper (Harrison et al. 2014). The methodologies included in the review papers were diverse and only one paper solely reviewed RCT studies (Stellamanns et al. 2017). Three papers included both RCT and non-randomized control trials and two papers included quantitative studies of any kind. A mixture of quantitative and qualitative methodologies was included in 12 papers. As such the estimated effects of the interventions on understanding were only stated for one study (Edwards et al. 2000) and similarly, one paper conducted a meta-analysis (Andreadis et al. 2021).

3.2 | Findings

The results from the review are outlined in Table 1 (and Table S1), with 4 themes identified: (1) understanding probability and uncertainty, (2) presentation of risk and probability information, (3) framing of risk information, and (4) the process of risk communication. Some of the terms used in this review may not be as widely used in climate change research and as such examples of the terms are provided in Table 2.

3.2.1 | Understanding Probability and Uncertainty

Ten of the review papers directly assessed whether people understood probabilities, risk and/or uncertainty information. Ghosh and Ghosh (2005) reviewed papers that tested medical physicians', patients' and medical students' comprehension of probabilities related to diagnostic tests. There was a wide range in how probability statistics were understood within the three participant groups, and it was common for physicians and students to overestimate particular diagnostic test probabilities. The Ripberger et al. (2022) study reviewed literature on various risks to identify ways to include probability information in communications and related it to weather forecasts. They found that confidence intervals and forecast periods were often misunderstood, as people interpreted the risk probability to be greatest at the end of the timeframe given. However, the review concluded that, with careful explanation, forecast probabilities can be understood by the general public. The focus of Møllebæk et al. (2019) was the effective communication of drug risk information to healthcare providers (HCPs). The HCPs in the United States found that the risk information they received about drugs was lacking in clarity; however this was not reported in other countries. A study reviewed how Radiofrequency Electromagnetic Fields (RF-EMF) mobile communication risks are communicated (Boehmert et al. 2020). They could not calculate the effect size for comprehension in this study as the number of comprehension studies was too small; however they suggested that simplified messages with less technical language were better understood. Meanwhile in Andreadis et al. (2021), they assessed how lay people interpret medical and health risks. They found that the way in which people interpret verbal probabilities (e.g., "very likely") does not correspond to their numerical probabilities.

TABLE 1 | Final list of the 17 systematic review studies that were included in the review of reviews.

Title	Authors	Number of studies included	Participant group	Risk Type	Methods included	Main objective	Summary of findings
Visualizing risks in cancer communication: A systematic review of computer-supported visual aids	Stellamanns et al. (2017)	13	Lay people or patients	Health/medical	RCT (Randomized Control Trial)	Review literature on computer supported visual aids for behavior, comprehension and preference	Static graphs (icon arrays, bar charts and pie charts) show some "promising results" on behavior intentions, comprehension, accuracy and preference compared to written text. Some studies found no or moderate effects. Dynamic/interactive graphs research is lacking and more research is needed before conclusions are made.
The effectiveness of one-to-one risks-communication interventions in health care: A systematic review	Edwards et al. (2000)	96 (effect size based on $n = 82$)	Not stated	Health/medical	RCT and non-RCT	Review literature on the effectiveness of clinical intervention to change patients knowledge and perception. Identify potential effect modifiers on risk communication	Risk communication interventions were generally associated with positive (beneficial) effects. Interventions using individual risk estimates were associated with larger effects than were those using more general risk information. Outcome variables included perception, behavior, anxiety and knowledge.
A systematic review of risk communication in clinical trials: How does it influence decisions to participate and what are the best methods to improve understanding in a trial context?	Coyle and Gillies (2020)	7	Hypothetical and real potential clinical trial volunteers.	Health/medical	RCT and non-RCT	Review evidence on methods for communicating risk to potential trial participants during the informed consent process	No clear method for improving understanding of clinical trial risks. Risk framing and influence on understanding had mixed results. Quantitative formats, particularly frequency formats and some visual aids appear to have promise, but more research is required.

(Continues)

TABLE 1 | (Continued)

Title	Authors	Number of studies included	Participant group	Risk Type	Methods included	Main objective	Summary of findings
Imprecision and Preferences in Interpretation of Verbal Probabilities in Health: a Systematic Review	Andreadis et al. (2021)	33	Lay people	Health/medical	RCT and non-RCT	Assess patient interpretation of and preferences for verbal probability information	Interpretation of qualitative probability terms are variable, overlapping and do not link with the quantitative probabilities assigned by experts. Suggests quantitative probabilities are used. Quantitative probability estimates for verbal terms were higher than their actual assigned probabilities.
Evidence-based risk communication: A systematic review	Zipkin et al. (2014)	84	Patients or healthy volunteers	Health/medical	Quantitative	Review methods of communicating probabilistic information to patients and the effect on their cognitive and behavioral outcomes.	Visual aids (icon arrays and bar graphs) improved patients' understanding. Accuracy was lower and risk perception higher for qualitative descriptors compared to natural frequencies or icon arrays. Denominator neglect and effect of natural frequencies was heterogeneous.
Translating evidence-based information into effective risk communication: Current challenges and opportunities	Ghosh and Ghosh (2005)	52	Physicians, patients and students	Health/medical	Quantitative and qualitative	Physicians' understanding of probability statistics and terms, identify the modes and their effectiveness of how risk is communicated to patients	Physicians and medical students overestimating specific probabilistic statistics. Physicians have widely varying understanding of probability terms. Patients vary in their ability to grasp information about risk presented as numbers and percentages. Decision aids had an improved understanding but there is a lack of consensus of how to best communicate medical risk. Pictorial (infographics) may be an effective method to communicate risk.

(Continues)

TABLE 1 | (Continued)

Title	Authors	Number of studies included	Participant group	Risk Type	Methods included	Main objective	Summary of findings
Design Features of Graphs in Health Risk Communication: A Systematic Review	Ancker et al. (2006)	24	Patients	Health/medical	Quantitative and qualitative	Effect of graphics on quantitative reasoning, behavior change and preferences	For good quantitative judgments: graphical element should be proportional to the number it portrays. Graphs emphasizing numerator of a risk ratio more likely to promote behavior change. Bar charts, risk ladders, scales and sequentially arranged icons can help patients understand individual risk. Graphical features that improve quantitative reasoning are different to the ones that induce behavior change. Features that viewers may like may not improve quantitative reasoning or behavior change.
Perception and Communication of Flood Risks: A Systematic Review of Empirical Research	Kellens et al. (2013)	57	Not stated	Flood	Quantitative and qualitative	Explore literature on flood risk perceptions and flood risk communication	A lack of research and limited theoretical background on flood-risk communication. Hard to compare across studies due to difference in methodology and frameworks. Almost an absence of true risk communications research on flood risk & all such recommendations are vague.

(Continues)

TABLE 1 | (Continued)

Title	Authors	Number of studies included	Participant group	Risk Type	Methods included	Main objective	Summary of findings
Risk as an attribute in discrete choice experiments: A systematic review of the literature[a]	Harrison et al. (2014) (Systematic review)	117	Patients, healthcare staff	Health/medical	Quantitative and qualitative	Identify healthcare discrete choice experiments that incorporate risk and evaluate methods to present risk attributes	Risk attributes mostly communicated quantitatively (frequencies, percentages or combination of both). Denominators are presented differently (not always in natural frequencies). 22% studies communicated using both qualitative and quantitative probability descriptors. Risk was most often communicated as a point estimates without a range. Risk was framed negatively in 87% of studies. No consensus of a consistent approach to communicating or framing risk information for better understanding.
	Harrison et al. (2014) (Rapid narrative review)	99[a]	Patients, healthcare staff	Health/medical	Quantitative and qualitative	Review approaches to healthcare risk communication	Some studies reported qualitative probability descriptors did not aid understanding of information and was one of the least successful communication tool. No clear consensus but more general support for communicating risk through graphical or pictorial images, icon arrays and risk ladders.

(Continues)

TABLE 1 | (Continued)

Title	Authors	Number of studies included	Participant group	Risk Type	Methods included	Main objective	Summary of findings
Evaluating the Mental Models Approach to Developing a Risk Communication: A Scoping Review of the Evidence	Boase et al. (2017)	12	Various	Various (technology, disaster and health)	Quantitative and qualitative	Review studies that have evaluated communications using the Mental Models Approach to Risk Communication (MMARC)	Using MMARC had a positive effect on some (if not all) of the measured outcomes where knowledge was the most frequently used outcome ($n = 11$). Most reported a significant improvement in participant knowledge following exposure to MMARC. MMARC maybe a useful framework for risk communications. No consensus on risk communication format or length is superior as all methods improved knowledge.
Communicating Environmental Health Risks with Indigenous Populations: A Systematic Literature Review of Current Research and Recommendations for Future Studies	Boyd and Furgal (2019)	13	Indigenous populations	Environmental health	Quantitative and qualitative	Review the focus of environmental health risks to indigenous populations, effective communications & identify gaps and recommendations	Almost all studies successful communication strategy involves the affected population in design and delivery. Developing communication processes that engage with and include Indigenous populations in message design, using trusted spokespeople, create communications that are understandable to affected population.
The effectiveness of Direct to Healthcare Professional Communication (DHPC)—A systematic review of communication factor studies	Møllebæk et al. (2019)	16	Healthcare providers (HCP)	Health/medical	Quantitative and qualitative	Review, systematically appraise and assess the effectiveness of DHPC studies which report on the communication factors.	HCP found DHPCs lacked clarity (only by Americans HCP). HCP had different demands for the DHPCs as some want specific recommendations and others want facts or data that patients and HCP can use to make decisions. User knows best—risk communications starts and ends with the recipient. HCPs adapt communication based on patient literacy to improve understanding.

(Continues)

TABLE 1 | (Continued)

Title	Authors	Number of studies included	Participant group	Risk Type	Methods included	Main objective	Summary of findings
Communicating uncertainty during public health emergency events: A systematic review	Sopory et al. (2019)	46	Public	Emergency public health	Quantitative and qualitative	Identify effective ways to communicate uncertainties to public audiences, at-risk communities, and stakeholders.	Communicating explicit information about uncertainty is required and generally agreed but it must be consistent, noncontradictory, clear and easy to understand. Some studies highlight the negative impact of communicating uncertainty as public cannot understand and/or conceptualize scientific uncertainty. Uncertainty information is prone to misinterpretation by both public and scientists. Quantitative interpretation of qualitative probability descriptors is not completely accurate. Public health emergencies have a chain of decisions and information flows where uncertainty can propagate. Different public health emergency stakeholders understand and experience uncertainty differently and may make suboptimal decisions.
A systematic review of health risk communication about Electro-Magnetic Fields (EMFs) from wireless technologies	Boehmert et al. (2020)	28	Not stated	Health/medical	Quantitative and qualitative	Reviews risk communications literature in relation to Radio-Frequency (RF)-EMF mobile communication technologies risk	Less technical and simplified communications were better understood. Presence vs. absence of an uncertainty sentence did not have influence the assessment of scientific knowledge.

(Continues)

TABLE 1 | (Continued)

Title	Authors	Number of studies included	Participant group	Risk Type	Methods included	Main objective	Summary of findings
Communicating treatment risks and benefits to cancer patients: a systematic review of communication methods	van de Water et al. 2020	28	Cancer patients, healthy volunteers and HCP	Health/medical	Quantitative and qualitative	Summarize literature on methods of communicating probabilistic information for cognitive, attitudinal and behavioral outcomes	Less information at one time may improve understanding, but heterogeneity in cognitive results. Precise, defined risk (in percentage/frequency formats) about side effects were better understood compared to qualitative information. Potential source of recall bias in this result. Inconclusive results about most effective graphic type. Results were quite mixed and various methodologies are a barrier to making further conclusions.
Cardiovascular risk communication strategies in primary prevention. A systematic review with narrative synthesis	Schulberg et al. (2022)	31	Individuals without known cardiovascular disease	Health/medical	Quantitative and qualitative	Evaluate effectiveness of cardiovascular risk communication strategies for improved understanding and to promote risk changes	Heterogeneity in outcomes and study design. Nine different categories of cardiovascular risk communication strategies were identified. Cardiovascular heart imaging and heart age (health of heart) were most effective at communicating risk, and bar charts, percentages and infographics were less effective. Conclusions for improving understanding are absent.

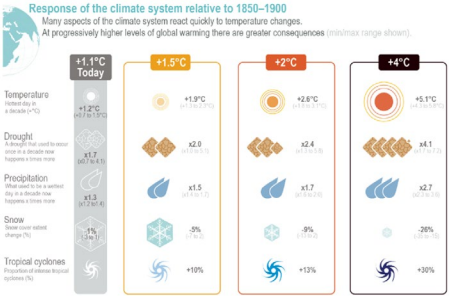
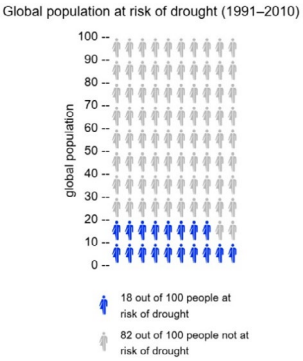
(Continues)

TABLE 1 | (Continued)

Title	Authors	Number of studies included	Participant group	Risk Type	Methods included	Main objective	Summary of findings
Communicating Probability Information in Weather Forecasts: Findings and Recommendations from a Living Systematic Review of the Research Literature	Ripberger et al. (2022)	29	Not stated	Various (weather, disaster and health)	Quantitative and qualitative	Review literature on effective ways to communicate probability information and the evidence for various practises of risk communication	Better understanding when probabilistic forecasts are communicated compared to deterministic forecasts. Public can understand forecast probabilities but explanation of the forecast's events is required. Severity of communication, directionality, word choice are factors in the interpretation of probabilities. No general consensus on how to communicate probabilities in the numeric form (%, frequencies or odds) for comprehension, and likely depends on the context. Including probability information in weather forecasts improves comprehension but there is no consensus on the best way to do this.

[a]Harrison et al. (2014) is one study that includes a rapid narrative review and a systematic review.

TABLE 2 | Examples of key statistical terms, visuals and graphs.

Risk communication terms	Description	Example
Qualitative probabilities	Communication of probability using qualitative (verbal) descriptors	"Likely," "Very likely" (Mastrandrea et al. 2011)
Quantitative probabilities	Communication of probability using quantitative (numerical) descriptors	"66%–100% likelihood" (Mastrandrea et al. 2011)
Natural frequencies	Use of the same denominator value.	"1 in 10" and "5 in 10"
Infographic	Combination of data, diagrams, text, and images together to communicate complex, abstract or dense information (Dunlap and Lowenthal 2016)	 For IPCC Climate Future infographic example see https://www.ipcc.ch/report/ar6/wg1/figures/technical-summary/ts-infographics-figure-1
Decision aids	Assist informed decision making by providing (often health related) information about the decision and options available. Outcomes of the decisions are also provided, e.g., benefits, harms, uncertainties. (BMJ 2013)	For an example see BMJ (2013)
Positive (gain) framing	Messages framed with an emphasis on the positive outcomes of the problem or risk.	"By mitigating climate change, we can prevent further increases in winter floods in maritime regions and flash floods throughout Europe" (Spence and Pidgeon 2010)
Negative (loss) framing	Messages framed with an emphasis on the negative outcomes of the problem or risk.	"Without mitigating climate change, we will see further increases in winter floods in maritime regions and flash floods throughout Europe" (Spence and Pidgeon 2010)
Individual risk	Use of an individual's characteristics to calculate their personalized risk estimate	"Your personal risk of developing colon cancer in your lifetime is 9%" (Vromans et al. 2024)
Generic risk	Using the general population's characteristics to calculate a generic risk estimate	"The general risk of developing colon cancer in your lifetime is 9%" (Vromans et al. 2024)
Icon array	Visual communication of percentages using colored icons. Each colored icon represents a specific percentage (in the example in the next column each icon represents 1%) (Recchia et al. 2022)	 Created using Iconarray.com (Wang and Sun 2023)

Three papers explored the "denominator neglect" which occurs when the reader gives insufficient focus to the denominator and instead, more focus is given to the numerator which can result in misinterpretation of the probability (Mikušková 2015). In Ancker et al. (2006), they explored how graphics influence the quantitative reasoning of quantitative health risks amongst patients as well as patients' behavior and preference. They established that patient comprehension is better when the ratio denominators are the same (also known as natural frequencies). For example, it is easier to compare 1 in 10 with 2 in 10 than to compare 1 in 10 with 1 in 5. Yet denominators are presented in many different ways in the healthcare context (Harrison et al. 2014). Finally, the denominator neglect findings were heterogeneous in Zipkin et al. (2014) review of communicating probabilistic health risks; however, the review found that natural frequencies were easier for people to understand, in line with Ancker et al. (2006). As such there appears to be evidence that people find it easier to understand risks when they are communicated using natural frequencies and may mitigate against the denominator neglect.

Of the 10 papers that reviewed understanding probability, 5 included understanding of uncertainty, though the conceptualization of uncertainty varies slightly across the studies. Harrison et al. (2014) reviewed studies that used discrete choice experiments to evaluate methods of presenting healthcare-related risks to patients and healthcare staff. They found that risk is most commonly presented as a point estimate with no inclusion of range or variability to signify the uncertainty, which influences the understanding of risk. In Boehmert et al.'s (2020) RF-EMF review, scientific knowledge comprehension was not influenced by the presence or absence of an uncertainty statement. Meanwhile, Ripberger et al. (2022) discovered that people can infer uncertainty when given a deterministic forecast but understanding can be improved by providing a probabilistic forecast that acknowledges uncertainty. However, as previously mentioned, people misinterpret confidence intervals, suggesting people's ability to grasp uncertainty and ranges may be limited. A review of effective cardiovascular risk communications to improve understanding was the focus of Schulberg et al. (2022). They concluded that individuals' uncertainties of risk were reduced when people were provided with a direct and personal communication such as cardiovascular imaging. Finally, Sopory et al.'s (2019) review was specifically focused on how to communicate the uncertainty of emergency public health risks to the general public, stakeholders, and vulnerable groups. They outline that the general public often misinterpret uncertainty information and scientists and some members of society are unable to conceptualize or understand uncertainty. Despite this they conclude that the communication of uncertainty should be carried out in a clear and non-contradictory way.

Overall, the review of reviews highlights that the comprehension of probability and uncertainty information varies amongst both the general population and domain experts. Evidence reviewed in this body of literature demonstrates that the presentation of probabilistic information can be improved by reducing the cognitive effort people need to expend, for example by using natural frequencies that facilitate easy comparison. Additionally, people can infer uncertainty from deterministic information and providing uncertainty information can improve comprehension and judgment, though care must be taken in communicating uncertainty to ensure it is not confusing.

3.2.2 | Presentation of Risk and Probability Information

Twelve studies reviewed the alternative ways of presenting risk information and their impact on understanding. Namely studies focused on (1) visual or graphic aids such as icon arrays, graphs and infographics and/or (2) comparison of quantitative versus qualitative probability descriptors.

Decision aids of various formats and media had a positive impact on patients understanding and pictorial communications show some promising results, however, there is a lack of consensus on the most effective way to communicate medical risks (Ghosh and Ghosh 2005). In a number of studies, graphical or pictorial images were identified as effective methods for communicating risk, but study heterogeneity and mixed results made it difficult to draw conclusions (Coyle and Gillies 2020; Ghosh and Ghosh 2005; Harrison et al. 2014; Stellamanns et al. 2017; Zipkin et al. 2014). Icon arrays, in particular, were suggested as a valuable method for communicating risk as they convey gist, or compare the risk to other well-known risks (Ancker et al. 2006; Harrison et al. 2014; Ripberger et al. 2022; Stellamanns et al. 2017; Zipkin et al. 2014). Meanwhile, bar charts also showed promise as a communication method for improving understanding (Ancker et al. 2006; Stellamanns et al. 2017; Zipkin et al. 2014) as did risk ladders (Ancker et al. 2006; Harrison et al. 2014). However, Schulberg et al. (2022) study of cardiovascular risk found bar charts and infographics were less successful at improving understanding compared to heart age and cardiovascular imaging and that generally, graphical formats had a mixed effect on understanding. However, this finding may be due to heart age and cardiovascular imaging communicating individual risk, while bar charts and infographics communicated generic risk. Meanwhile, reviews on flood risk communications (Kellens et al. 2013) and communicating probabilistic risk information about cancer treatment (van de Water et al. 2020) found such diverse results that no conclusion could be made.

The issue of complexity in risk information was raised by two studies. While patients may prefer simple graphs, they are not always suitable for communicating complex information (Ancker et al. 2006). In the context of weather forecasts, Ripberger et al. (2022) highlight the distinction between visualizations which emphasize the most likely outcome, versus visualizations which emphasize the potential for alternative possibilities (in the case of weather forecasts as in climate, this may include showing individual model simulations with a range of outcomes). The latter approach has been found to be helpful for improving awareness of risk and possible options, but it may also distract from the most likely outcomes.

The comparison of quantitative and qualitative communication of probability information was conducted by eight reviews. Qualitative descriptors of probability information were found to be less effective at improving understanding than quantitative

methods (Andreadis et al. 2021; Harrison et al. 2014; van de Water et al. 2020; Zipkin et al. 2014). The qualitative descriptors of healthcare-related risks were one of the least successful ways to communicate risk in Harrison et al. (2014) and patients had lower understanding of qualitative descriptors compared to natural frequencies, event rates (e.g., 63 deaths per 100,000 population) or icon arrays in Zipkin et al. (2014). Similarly, percentage and frequency formats about the side effects of cancer treatments were better understood by cancer patients, healthy participants and HCPs than qualitative descriptors of probability information, although they highlight that the results may have been biased by the design of the studies due to recall bias (van de Water et al. 2020).

Qualitative descriptors of probability (e.g., "likely") are usually associated with a quantitative estimate (e.g., 66%–100% likelihood) by those generating risk information. However when given qualitative descriptors of probability, people can associate these with the incorrect quantitative likelihood estimates or the interpretation of qualitative descriptors (e.g., "likely" and "very likely") may overlap with one another (Andreadis et al. 2021; Sopory et al. 2019). In the case of the term "common" which, in this specific context, had an expert assigned numeric estimate of 58.7%, lay people gave estimates ranging between 10% and 100% (Andreadis et al. 2021). While quantitative probabilities can sometimes improve understanding, they are still open to misinterpretations and qualitative descriptors were found to be effective at improving understanding of cardiovascular risk (Schulberg et al. 2022). Quantitative and qualitative descriptors of probability may be understood differently depending on the level of numeracy of the reader (Ripberger et al. 2022), and as such quantitative and qualitative descriptors may be best presented alongside each other (Andreadis et al. 2021; Ripberger et al. 2022).

The review of reviews has therefore identified key findings on how the presentation of risk influences understanding. Icon arrays and bar charts generally improve understanding of information, though further research is required for other types of graphics, and context is likely to play a role. Icon arrays, in particular, are health risk specific and often communicate the likelihood of people being affected. Meanwhile, presenting probability information in a quantitative way is more effective for improving understanding than using associated qualitative descriptors, due to ambiguity in how verbal probabilities are interpreted.

3.2.3 | Framing of Risk Information

The way risk information is framed in communication and its effect on understanding was reviewed by six papers and includes loss/gain or positive/negative framing, and individual versus generic risk framing (see Table 2 for examples). Framing gives some elements of a complex problem more emphasis to assist readers in understanding the risks, why it matters and what should be done (Nisbet and Mooney 2007). Harrison et al. (2014) found that 87% of healthcare-related risks were framed negatively. The way a risk is framed was found to influence understanding; however the direction of this influence was inconclusive due to mixed results (Coyle and Gillies 2020; Ripberger et al. 2022; van de Water et al. 2020). Meanwhile communicating that "an event will occur" versus "an event will not occur" has an impact on how people estimate the probability of the event. When the event is framed to occur, people overestimate the event's probability. When the event is framed to not occur, people underestimate the probability.

The comparison of individual and generic risk communication was reviewed by two papers, focused on health risks. The sole review in this review of reviews that calculated the effect size explored health risks such as coronary heart disease, HIV, smoking and cancers. They calculated that the individual risk estimates had a larger effect than generic risk estimates. However, the outcome variables used to measure the effect size included perception, behavior, and anxiety as well as knowledge rather than knowledge alone (Edwards et al. 2000). Meanwhile in a review of cardiovascular disease risk communication, there was no conclusion on the influence of individual cardiovascular risk on understanding (Schulberg et al. 2022). Overall, there is evidence that framing influences understanding but there is no consensus on the direction of this influence.

3.2.4 | The Process of Risk Communication

Five review papers explored the processes that occur when developing risk communications. Boyd and Furgal (2019) reviewed literature on environmental health risk communications for Indigenous populations. They found that engaging with indigenous populations to develop risk communications that had suitable message design, were tailored to the context, and used suitable, culturally sensitive language, were more likely to be understood by the population. Boase et al. (2017) reviewed studies that have adopted the mental models approach to risk communication (MMARC). MMARC follows a five-step process which includes engagement with stakeholders to understand their mental models and evaluating communications with the target population (Morgan 2002). MMARC acknowledges that people's views and knowledge are influenced by experiences, external information sources and complex information, some of which may not be accurate. An MMARC approach resulted in significant improvements in people's knowledge, and they conclude it is a useful framework for developing such communications.

In the healthcare setting, HCPs had different requirements for the types of drug risk communications they receive (Møllebæk et al. 2019). While some wanted specific recommendations, others wanted facts that could be used to inform patients' decision making. HCPs adapt the risk communication they receive depending on their patients' literacy so that the information is better understood. Similarly, in public health emergencies it is highlighted that there is a flow of information and decision making, within which uncertainty can propagate (Sopory et al. 2019). If this information flow is unclear, contradictory or inconsistent it can result in confusion and poor decision-making. They also note that this flow of information can be hindered if experts and policymakers understand, and experience, uncertainty in different ways. Finally, in a review of probability information for cancer treatment risks, authors suggest that providing smaller amounts of information over a long period of time could improve understanding (van de Water et al. 2020).

Overall, consideration and interaction with the end user can improve their understanding of the risk and make an informed decision. The flow of information is also an important consideration as experts make decisions about how and when the information is passed along.

4 | Discussion

We have reviewed 17 review papers to explore literature on risk communications for improved understanding. Based upon this study five key findings that are relevant for communicating future climate information will be discussed.

1. Lay people and scientists alike struggle to interpret probability information.

The review has found that many people, including experts and scientists, misinterpret probabilities and statistics. When communicating uncertain future climate information, it is important to try and reduce the mental load of interpretation for all involved, including scientists. In a study with participants from climate-adjacent UK organizations, 79% and 46% of participants described probability estimates as a feature that hindered their understanding of maps and graphs, respectively (Kause et al. 2020). When communicating climate projection probabilities and statistics (such as relative change or percentiles) care should be taken to explain them and not assume that they will be correctly interpreted by people, even those who are in the field of climate change.

2. Differences in interpretation of qualitative and quantitative probability descriptors.

Qualitative descriptors for probability (e.g., "very likely") are not as well understood as quantitative descriptors (e.g., 90%–100% likelihood). The IPCC has calibrated language and frameworks for likelihoods which include quantitative and qualitative descriptions (Mastrandrea et al. 2011). These have also been adopted beyond IPCC reports. Despite a calibrated framework, IPCC authors disagree on how to communicate probabilistic information (Janzwood 2020).

3. Use natural frequencies when communicating ratios.

The review found that using a common denominator (e.g., 1 in 10 and 2 in 10, rather than 1 in 10 and 1 in 5) can improve people's understanding. This may be relevant when talking about future risks such as floods and their return periods which are often communicated as a "1 in 100-year event" or "1 in 5-year event." However, further research is required as people misinterpret the likelihood of a risk when it is communicated as a return period, especially if that event has occurred recently (Grounds et al. 2018).

4. Icon arrays can enhance comprehension.

Although such visualizations are not widely used for communicating climate projections icon arrays could be an effective and new method for climate communications. Similarly, infographics could provide aesthetic and well-explained information about climate risk. Given IPCC graphics can be too complicated, icon arrays (Fischer et al. 2018; McMahon et al. 2015) might be a simpler option for future documents.

5. Interaction with information users and drip-feeding information can improve understanding.

This resonates well with processes in climate services, where working with decision-makers over a long period of time, and collaborating to co-produce information has been found to create shared understanding (Jack et al. 2020). Mental models could be a useful way to identify how people understand climate information and improve communications (Mayer et al. 2017).

While there are key takeaways for communicating climate risk from this predominately health-focused review of reviews, some findings are not as relevant. There are three areas including: timeframe of the risk; communicating individual risk instead of generic risk; and the visualizations of risk information.

This study has found individual risks can be a more appropriate method for communicating risk compared to generic risk. Communication of individual risk in the context of climate risk is not common and the low spatial resolutions of climate projections make it challenging to provide personalized climate information (Smid and Costa 2018). Regarding the timeframe of the risk, in a healthcare or emergency setting there may be less time to properly interpret probabilistic information and the risk is more imminent than climate risks. Although IPCC scientists have limited time to work on reports and assign confidence and likelihood estimates (Janzwood 2020; Kause et al. 2022), it cannot be compared to the healthcare or emergency public health context in which some of these studies are placed. Finally, the health and climate disciplines use different visualizations. Line (plume) plots, box plots and maps are more common ways of visualizing climate projections. While bar charts are sometimes used in seasonal forecasts, they are not currently used within climate projections. Meanwhile decision aids or support tools have different goals within healthcare and climate, with the former aiming to support individual patient decision making or changing behavior. Meanwhile, a decision aid, in the context of climate adaptation, may come in the form of a climate service and is likely to be developed specifically for targeted sectoral decision makers within organizations and businesses (Vincent et al. 2018).

This review of reviews may have been limited by the focus on "risk communication," there may be other studies on communicating uncertainties that were not identified. Furthermore, as this was a review of reviews, it was challenging to get a detailed understanding of all the methodologies used in the studies included in the review papers. It is also difficult to get a detailed view of the participants in each study, and how their experience, education and background might influence the findings. Where consensus could not be reached in the review studies, it may have been due to heterogeneity in methodology, study design and contexts. As such, it is challenging to assess whether uncertainties are due to genuine variation between people in how they interpret information, or due to differences in the methods or contexts. However, it is worth noting that five of the reviews highlighted a need for improved study designs. While the

reviews covered here focus on the communication of risk and uncertainty, it should be noted that none fully considered how metacognition (a recipients' awareness and insights into their own reasoning, and motivational biases) may affect how information is interpreted.

Given risk communication and systematic reviews have their roots in the medical and health disciplines, it is no surprise that the studies in this review are dominated by health and medical risks. Nevertheless, the review has highlighted useful insights that could be applied in climate communications. Additionally, it highlights the need for risk communication research focusing on future climate information, for example to test common climate visualizations such as plume plots and maps. Finally, the countries included in the studies in this review, as well as lead authorship, are not representative of all regions. More research is urgently needed on regions outside of North America and Europe, as cross-country and culture differences exist in the interpretation of risk information (Daron et al. 2015 and Kause et al. 2020).

5 | Conclusion

This review identified reviews which specifically focused on risk communications for improved understanding. Although all risk types were included, the majority were in the health discipline, and as such, may not be journals that climate researchers read. The study design, contexts and risk types were highly heterogeneous, making it difficult to generalize; however, there are findings that are relevant to climate change. These include the effectiveness of bar charts and icon arrays; the varied comprehension of probabilistic information and uncertainty information, ineffectiveness of qualitative descriptors of probability information compared to quantitative descriptors and the improvement of understanding of risks when adopting a collaborative design of risk communication.

Author Contributions

Ailish Craig: conceptualization (equal), data curation (equal), formal analysis (lead), investigation (equal), methodology (lead), visualization (lead), writing – original draft (lead), writing – review and editing (equal). **Andrea Taylor:** conceptualization (equal), data curation (supporting), formal analysis (supporting), investigation (supporting), methodology (supporting), writing – original draft (supporting), writing – review and editing (equal). **Anna Steynor:** conceptualization (equal), investigation (equal), methodology (supporting), writing – original draft (supporting), writing – review and editing (equal). **Christopher Shaw:** conceptualization (equal), writing – review and editing (equal). **Alice McClure:** conceptualization (equal), writing – review and editing (equal). **Rachel A. James:** conceptualization (equal), data curation (equal), formal analysis (supporting), funding acquisition (lead), investigation (equal), methodology (equal), supervision (lead), writing – original draft (supporting), writing – review and editing (equal).

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

Related WIREs Articles

Theory and language of climate change communication

Climate change communication: what can we learn from communication theory?

Changing behavioral responses to heat risk in a warming world: How can communication approaches be improved?

References

Ancker, J. S., Y. Senathirajah, R. Kukafka, and J. B. Starren. 2006. "Design Features of Graphs in Health Risk Communication: A Systematic Review." *Journal of the American Medical Informatics Association: JAMIA* 13, no. 6: 608–618. https://doi.org/10.1197/jamia.M2115.

Andreadis, K., E. Chan, M. Park, et al. 2021. "Imprecision and Preferences in Interpretation of Verbal Probabilities in Health: A Systematic Review." *Journal of General Internal Medicine* 36, no. 12: 3820–3829. https://doi.org/10.1007/s11606-021-07050-7.

BMJ (Clinical Research Ed.). 2013. "An Introduction to Patient Decision Aids." *BMJ* 347: f4147. https://doi.org/10.1136/bmj.f4147.

Boase, N., M. White, W. Gaze, and C. Redshaw. 2017. "Evaluating the Mental Models Approach to Developing a Risk Communication: A Scoping Review of the Evidence." *Risk Analysis* 37, no. 11: 2132–2149. https://doi.org/10.1111/risa.12789.

Boehmert, C., F. Freudenstein, and P. Wiedemann. 2020. "A Systematic Review of Health Risk Communication About EMFs From Wireless Technologies." *Journal of Risk Research* 23, no. 5: 571–597. https://doi.org/10.1080/13669877.2019.1592211.

Boyd, A. D., and C. M. Furgal. 2019. "Communicating Environmental Health Risks With Indigenous Populations: A Systematic Literature Review of Current Research and Recommendations for Future Studies." *Health Communication* 34, no. 13: 1564–1574. https://doi.org/10.1080/10410236.2018.1507658.

Conway, D. 2024. "Water on the Mind: Mapping Behavioral and Psychological Research on Water Security. WIREs." *Water* e1755. https://doi.org/10.1002/wat2.1755.

Coyle, M., and K. Gillies. 2020. "A Systematic Review of Risk Communication in Clinical Trials: How Does It Influence Decisions to Participate and What Are the Best Methods to Improve Understanding in a Trial Context?" *PLoS One* 15, no. 11: e0242239. https://doi.org/10.1371/journal.pone.0242239.

Daron, J., S. Lorenz, A. Taylor, and S. Dessai. 2021. "Communicating Future Climate Projections of Precipitation Change." *Climatic Change* 166, no. 1: 23. https://doi.org/10.1007/s10584-021-03118-9.

Daron, J. D., S. Lorenz, P. Wolski, R. C. Blamey, and C. Jack. 2015. "Interpreting Climate Data Visualisations to Inform Adaptation Decisions." *Climate Risk Management* 10: 17–26. https://doi.org/10.1016/j.crm.2015.06.007.

Dunlap, J. C., and P. R. Lowenthal. 2016. "Getting Graphic About Infographics: Design Lessons Learned From Popular Infographics." *Journal of Visual Literacy* 35, no. 1: 42–59. https://doi.org/10.1080/1051144X.2016.1205832.

Edwards, A., K. Hood, E. Matthews, et al. 2000. "The Effectiveness of One-To-One Risk-Communication Interventions in Health Care: A Systematic Review." *Medical Decision Making* 20, no. 3: 290–297. https://doi.org/10.1177/0272989X0002000305.

Fischer, H., S. Schütte, A. Depoux, D. Amelung, and R. Sauerborn. 2018. "How Well Do COP22 Attendees Understand Graphs on Climate Change Health Impacts From the Fifth IPCC Assessment Report?" *International Journal of Environmental Research and Public Health* 15, no. 5: 5. https://doi.org/10.3390/ijerph15050875.

Ghosh, A. K., and K. Ghosh. 2005. "Translating Evidence-Based Information Into Effective Risk Communication: Current Challenges and Opportunities." *Journal of Laboratory and Clinical Medicine* 145, no. 4: 171–180. https://doi.org/10.1016/j.lab.2005.02.006.

Grant, M. J., and A. Booth. 2009. "A Typology of Reviews: An Analysis of 14 Review Types and Associated Methodologies." *Health Information and Libraries Journal* 26, no. 2: 91–108. https://doi.org/10.1111/j.1471-1842.2009.00848.x.

Grounds, M. A., J. E. LeClerc, and S. Joslyn. 2018. "Expressing Flood Likelihood: Return Period Versus Probability." *Weather, Climate, and Society* 10: 5–17. https://doi.org/10.1175/WCAS-D-16-0107.1.

Harrison, M., D. Rigby, C. Vass, T. Flynn, J. Louviere, and K. Payne. 2014. "Risk as an Attribute in Discrete Choice Experiments: A Systematic Review of the Literature." *Patient* 7, no. 2: 151–170. https://doi.org/10.1007/s40271-014-0048-1.

Hewitson, B., K. Waagsaether, J. Wohland, K. Kloppers, and T. Kara. 2017. "Climate Information Websites: An Evolving Landscape." *WIREs Climate Change* 8, no. 5: e470. https://doi.org/10.1002/wcc.470.

Jack, C. D., R. Jones, L. Burgin, and J. Daron. 2020. "Climate Risk Narratives: An Iterative Reflective Process for Co-Producing and Integrating Climate Knowledge." *Climate Risk Management* 29: 100239. https://doi.org/10.1016/j.crm.2020.100239.

James, R., R. Washington, and D. P. Rowell. 2014. "African Climate Change Uncertainty in Perturbed Physics Ensembles: Implications of Global Warming to 4°C and Beyond." *Journal of Climate* 27, no. 12: 4677–4692. https://doi.org/10.1175/JCLI-D-13-00612.1.

Janzwood, S. 2020. "Confident, Likely, or Both? The Implementation of the Uncertainty Language Framework in IPCC Special Reports." *Climatic Change* 162, no. 3: 1655–1675. https://doi.org/10.1007/s10584-020-02746-x.

Kause, A., W. Bruine de Bruin, J. Persson, et al. 2022. "Confidence Levels and Likelihood Terms in IPCC Reports: A Survey of Experts From Different Scientific Disciplines." *Climatic Change* 173, no. 1: 2. https://doi.org/10.1007/s10584-022-03382-3.

Kause, A., W. B. de Bruin, F. Fung, A. Taylor, and J. Lowe. 2020. "Visualizations of Projected Rainfall Change in the United Kingdom: An Interview Study About User Perceptions." *Sustainability* 12, no. 7: 2955. https://doi.org/10.3390/su12072955.

Kellens, W., T. Terpstra, and P. De Maeyer. 2013. "Perception and Communication of Flood Risks: A Systematic Review of Empirical Research." *Risk Analysis* 33, no. 1: 24–49. https://doi.org/10.1111/j.1539-6924.2012.01844.x.

Lorenz, S., S. Dessai, P. M. Forster, and J. Paavola. 2015. "Tailoring the Visual Communication of Climate Projections for Local Adaptation Practitioners in Germany and the UK." *Philosophical Transactions of the Royal Society a-Mathematical Physical and Engineering Sciences* 373, no. 2055: 20140457. https://doi.org/10.1098/rsta.2014.0457.

Mastrandrea, M. D., K. J. Mach, G.-K. Plattner, et al. 2011. "The IPCC AR5 Guidance Note on Consistent Treatment of Uncertainties: A Common Approach Across the Working Groups." *Climatic Change* 108, no. 4: 675–691. https://doi.org/10.1007/s10584-011-0178-6.

Mayer, L. A., K. Loa, B. Cwik, et al. 2017. "Understanding Scientists' Computational Modeling Decisions About Climate Risk Management Strategies Using Values-Informed Mental Models." *Global Environmental Change* 42: 107–116. https://doi.org/10.1016/j.gloenvcha.2016.12.007.

McMahon, R., M. Stauffacher, and R. Knutti. 2015. "The Unseen Uncertainties in Climate Change: Reviewing Comprehension of an IPCC Scenario Graph." *Climatic Change* 133, no. 2: 141–154. https://doi.org/10.1007/s10584-015-1473-4.

Mikušková, E. B. 2015. "The Denominator Neglect in Decision-Making." *Studia Psychologica* 57, no. 4: 255–270. https://doi.org/10.21909/sp.2015.03.698.

Moher, D., A. Liberati, J. Tetzlaff, and D. G. Altman. 2009. "Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement." *BMJ*. https://doi.org/10.1136/bmj.b2535.

Møllebæk, M., S. Kaae, M. L. De Bruin, T. Callréus, S. Jossan, and C. E. Hallgreen. 2019. "The Effectiveness of Direct to Healthcare Professional Communication—A Systematic Review of Communication Factor Studies." *Research in Social & Administrative Pharmacy: RSAP* 15, no. 5: 475–482. https://doi.org/10.1016/j.sapharm.2018.06.015.

Morgan, M. G. 2002. *Risk Communication: A Mental Models Approach*. Cambridge University Press.

Newson, M., M. Buhrmester, D. Xygalatas, and H. Whitehouse. 2018. "Go WILD, Not WEIRD." *Journal for the Cognitive Science of Religion* 6, no. 1–2: 80–106. https://doi.org/10.1558/jcsr.38413.

Nisbet, M. C., and C. Mooney. 2007. "Framing Science." *Science* 316, no. 5821: 56. https://doi.org/10.1126/science.1142030.

Pidgeon, N. 2012. "Climate Change Risk Perception and Communication: Addressing a Critical Moment?" *Risk Analysis* 32, no. 6: 951–956. https://doi.org/10.1111/j.1539-6924.2012.01856.x.

Pidgeon, N., and B. Fischhoff. 2011. "The Role of Social and Decision Sciences in Communicating Uncertain Climate Risks." *Nature Climate Change* 1, no. 1: 35–41. https://doi.org/10.1038/nclimate1080.

Porter, J. J., and S. Dessai. 2017. "Mini-Me: Why Do Climate Scientists' Misunderstand Users and Their Needs?" *Environmental Science & Policy* 77: 9–14. https://doi.org/10.1016/j.envsci.2017.07.004.

Recchia, G., A. C. E. Lawrence, and A. L. J. Freeman. 2022. "Investigating the Presentation of Uncertainty in an Icon Array: A Randomized Trial." *PEC Innovation* 1: 100003. https://doi.org/10.1016/j.pecinn.2021.100003.

Ripberger, J., A. Bell, A. Fox, et al. 2022. "Communicating Probability Information in Weather Forecasts: Findings and Recommendations From a Living Systematic Review of the Research Literature." *Weather, Climate, and Society* 14, no. 2: 481–498. https://doi.org/10.1175/WCAS-D-21-0034.1.

Rodgers, M., A. Sowden, M. Petticrew, et al. 2009. "Testing Methodological Guidance on the Conduct of Narrative Synthesis in Systematic Reviews: Effectiveness of Interventions to Promote Smoke Alarm Ownership and Function." *Evaluation* 15, no. 1: 49–73. https://doi.org/10.1177/1356389008097871.

Salas Reyes, R., V. M. Nguyen, S. Schott, et al. 2021. "A Research Agenda for Affective Dimensions in Climate Change Risk Perception and Risk Communication." *Frontiers in Climate* 3: 751310. https://doi.org/10.3389/fclim.2021.751310.

Schipper, E. L. F. 2020. "Maladaptation: When Adaptation to Climate Change Goes Very Wrong." *One Earth* 3, no. 4: 409–414. https://doi.org/10.1016/j.oneear.2020.09.014.

Schulberg, S. D., A. V. Ferry, K. Jin, et al. 2022. "Cardiovascular Risk Communication Strategies in Primary Prevention. A Systematic Review With Narrative Synthesis." *Journal of Advanced Nursing* 78, no. 10: 3116–3140. https://doi.org/10.1111/jan.15327.

Shepherd, T. G. 2014. "Atmospheric Circulation as a Source of Uncertainty in Climate Change Projections." *Nature Geoscience* 7, no. 10: 703–708. https://doi.org/10.1038/ngeo2253.

Smid, M., and A. C. Costa. 2018. "Climate Projections and Downscaling Techniques: A Discussion for Impact Studies in Urban Systems." *International Journal of Urban Sciences* 22, no. 3: 277–307. https://doi.org/10.1080/12265934.2017.1409132.

Sopory, P., A. M. Day, J. M. Novak, et al. 2019. "Communicating Uncertainty During Public Health Emergency Events: A Systematic Review." *Review of Communication Research* 7: 67–108. https://doi.org/10.12840/ISSN.2255-4165.019.

Spence, A., and N. Pidgeon. 2010. "Framing and Communicating Climate Change: The Effects of Distance and Outcome Frame

Manipulations." *Global Environmental Change* 20, no. 4: 656–667. https://doi.org/10.1016/j.gloenvcha.2010.07.002.

Steg, L., A. E. van Berg, and J. I. M. de Groot. 2012. *Environmental Psychology: An Introduction*. John Wiley & Sons.

Stellamanns, J., D. Ruetters, K. Dahal, Z. Schillmoeller, and J. Huebner. 2017. "Visualizing Risks in Cancer Communication: A Systematic Review of Computer-Supported Visual Aids." *Patient Education and Counseling* 100, no. 8: 1421–1431. https://doi.org/10.1016/j.pec.2017.02.003.

Steynor, A., J. Padgham, C. Jack, B. Hewitson, and C. Lennard. 2016. "Co-Exploratory Climate Risk Workshops: Experiences From Urban Africa." *Climate Risk Management* 13: 95–102. https://doi.org/10.1016/j.crm.2016.03.001.

Tall, A., J. Y. Coulibaly, and M. Diop. 2018. "Do Climate Services Make a Difference? A Review of Evaluation Methodologies and Practices to Assess the Value of Climate Information Services for Farmers: Implications for Africa." *Climate Services* 11: 1–12. https://doi.org/10.1016/j.cliser.2018.06.001.

van de Water, L. F., J. J. van Kleef, W. P. M. Dijksterhuis, et al. 2020. "Communicating Treatment Risks and Benefits to Cancer Patients: A Systematic Review of Communication Methods." *Quality of Life Research* 29, no. 7: 1747–1766. https://doi.org/10.1007/s11136-020-02503-8.

Vincent, K., D. Conway, A. J. Dougill, et al. 2020. "Re-Balancing Climate Services to Inform Climate-Resilient Planning – A Conceptual Framework and Illustrations From Sub-Saharan Africa." *Climate Risk Management* 29: 100242. https://doi.org/10.1016/j.crm.2020.100242.

Vincent, K., M. Daly, C. Scannell, and B. Leathes. 2018. "What Can Climate Services Learn From Theory and Practice of Co-Production?" *Climate Services* 12: 48–58. https://doi.org/10.1016/j.cliser.2018.11.001.

Vogel, C., A. Steynor, and A. Manyuchi. 2019. "Climate Services in Africa: Re-Imagining an Inclusive, Robust and Sustainable Service." *Climate Services* 15: 100107. https://doi.org/10.1016/j.cliser.2019.100107.

Vromans, R. D., L. M. A. van Goor, and S. C. Pauws. 2024. "Investigating the Psychological Impact of Communicating Epistemic Uncertainty in Personalized and Generic Risk Estimates: An Experimental Study." *Journal of Risk Research* 27: 1–15. https://doi.org/10.1080/13669877.2024.2368191.

Wang, T., and F. Sun. 2023. "Integrated Drought Vulnerability and Risk Assessment for Future Scenarios: An Indicator Based Analysis." *Science of the Total Environment* 900: 165591. https://doi.org/10.1016/j.scitotenv.2023.165591.

Wang, Y., and D. Gafurov. 2003. "The Cognitive Process of Comprehension." The Second IEEE International Conference on Cognitive Informatics, 2003. Proceedings, 93–97. https://doi.org/10.1109/COGINF.2003.1225963.

Zipkin, D. A., C. A. Umscheid, N. L. Keating, et al. 2014. "Evidence-Based Risk Communication: A Systematic Review." *Annals of Internal Medicine* 161, no. 4: 270–280. https://doi.org/10.7326/M14-0295.

Supporting Information

Additional supporting information can be found online in the Supporting Information section. **Table S1:**. Further details of the 17 review papers included in the review. **Data S1:** wcc70027-sup-0002-Supinfo.docx.