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Evidence-Based Recommendations for Communicating the Impacts of Climate Change on Health

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Abstract

Background. Climate change poses a multifaceted, complex, and existential threat to human health and well-being, but efforts to communicate these threats to the public lag behind what we know how to do in communication research. Effective communication about climate change's health risks can improve a wide variety of individual and population health-related outcomes by: (1) helping people better make the connection between climate change and health risks and (2) empowering them to act on that newfound knowledge and understanding.

Purpose. To highlight communication methods that have received empirical support for improving knowledge uptake and/or driving higher-quality decision making and healthier behaviors, and to recommend how to apply them at the intersection of climate change and health.

Methods. Expert consensus about effective communication methods that can be used by healthcare professionals, decisionmakers, governments, the general public, and other stakeholders including sectors outside of health.

Results. We argue for the use of eleven theory-based, evidence-supported communication strategies and practices. These methods range from leveraging social networks to making careful choices about the use of language, narratives, emotions, visual images, and statistics. Message testing with appropriate groups is also key.

Conclusions. When implemented properly, these approaches are likely to improve the outcomes of climate change and health communication efforts.

Keywords: communication; climate change; climate change and health; health and wellbeing; health disparities; political action

Lay Summary: Climate change poses a tremendous and complex threat to human health and well-being. Efforts to communicate these threats to the public may not be as effective as desired and using evidence-based strategies could improve a wide variety of health-related outcomes for individuals and society while potentially reducing climate-related health disparities. In particular, effective communication can help people understand the crucial connection between climate change and health risks and empower them to act on that newfound knowledge and understanding. We recommend eleven communication methods that have been well-tested in other domains and can be applied to the intersection of climate and health by healthcare professionals, decisionmakers, governments, the general public, and other stakeholders including those in sectors outside of health. These methods range from leveraging social networks to making careful choices about the use of language, narratives, emotions, visual images, and statistics. Message testing with appropriate groups is also key. When implemented properly, these approaches are likely to improve knowledge uptake and drive better decision making and healthier behaviors.

Evidence-Based Recommendations for Communicating the Impacts of Climate Change on Health

Climate change poses a multifaceted, complex, and existential threat to human health and well-being [1]. It is already harming health directly and indirectly through numerous pathways that vary by geographic region, and it underlies and exacerbates other health-related problems as it acts as a threat multiplier [2]. Although much remains to be studied, public health and medical research reveal a wide range of short- and long-term effects of climate change on human health at both individual and population levels. These impacts include increased and/or exacerbated disease burdens related to heat morbidity and mortality, respiratory and cardiovascular disease, vector-borne illnesses, nutrient penalties, worse mental health, maternal and fetal health harms, foodborne illness, and injuries from climate-intensified disasters such as flooding and wildfires [2-10]. While everyone is at risk from the health harms of climate change, certain populations disproportionately bear the brunt, such as those with comorbidities, low income communities, children and older persons, and those with health inequities from structural racism (e.g., Latinos, Black, Indigenous, and other people of color). Climate change also threatens the achievement of high-quality health care through its effects on supply chains, power delivery, health care utilization, and damage to health system infrastructure [11]. To put it succinctly: No aspect of human functioning and life will be left untouched over the coming decades as anthropogenic climate change radically reshapes the biogeophysical, economic, social, cultural, psychological, and health systems that we rely on for health [1].

Human-caused greenhouse gas emissions are driving climate change, largely through the burning of fossil fuels [3]. An equitable transition away from fossil fuels is cost-effective, especially when considering avoided health harms [5-10]. For example, renewable energy sources like wind and solar produce local, near-term health benefits today through reduced air pollution. Thus, the interventions needed to address the root causes of climate change exist, but a lack of political and collective will to act in the next decade may push the goals of the Paris Agreement outside our reach [1,3].

Despite the evidence about the health harms of climate change, efforts to communicate them to the public and decisionmakers lag behind what we know how to do in communication research. Improved

communication about these issues is needed to increase public and political demand for policies and actions so we can minimize the negative impacts of climate change on human well-being now and in the future [12]. Effective communication about climate change's health risks can improve a wide variety of individual and population health-related outcomes, including but not limited to:

- positive changes in individuals' health-related behaviors;
- improved public health in the face of compounding risks (e.g., climate-intensified disasters);
- shifts in how medical practitioners think about the short- and long-term environmental health risks their patients face, thus shaping treatment decisions;
- increased recognition of the interconnections between issues of health, environmental justice, and inequality [13];
- reductions in the economic and human costs of future climate-change-induced disasters (e.g., through the promotion of adaptation and mitigation strategies); and
- increased advocacy behaviors from the public aimed at sharply escalating responsible government and corporate behaviors and policies [see, 14 in this special issue]. This last factor may be the most important.

Thus, a critical need exists to develop, promote, and implement best practices for communicating the health risks associated with and exacerbated by climate change. It would certainly be easier if we could facilitate all-encompassing action on climate change by simply educating people about health-related climate risks, inequities, and mitigation strategies through familiar, top-down, "expert knows best" communication efforts. Yet, for a wide variety of reasons—well-known to the social, behavioral, and communication sciences— effective communication on climate change and health, in fact, does not emerge in this manner [15]. Fortunately, more effective communication strategies do exist that can be leveraged in this domain.

In the present paper, we first briefly describe related lessons learned from the COVID-19 pandemic. We then argue for the use of eleven theory-based, evidence-supported communication strategies and practices. These communication approaches were developed and then tested across the

pandemic and other medical and non-medical domains. Trusted messengers of all types—including healthcare professionals—can integrate these strategies and practices into their existing outreach, engagement, and communication efforts for two purposes: (1) to help people better make the connection between climate change and health risks in their own minds and (2) to empower them to act on that newfound knowledge and understanding. When implemented properly, these approaches are likely to improve the outcomes of our climate-change and health-communication efforts.

Lessons learned from COVID-19

The COVID-19 pandemic provided a tangible illustration of two important issues relevant to the linkage between climate change and health. First, human activity indeed affects our environment. Measures implemented to mitigate COVID-19's spread had significant positive—albeit temporary—effects on the environment. Lockdowns and lower economic activity, for example, reduced air pollution, water contamination, greenhouse gas emissions, and environmental noise [16-17]. Second, communication lessons learned (and re-learned) during the pandemic point towards how we should (and should *not*) communicate about issues at the intersection of climate change and health. The most relevant lessons learned include:

- Evidence-based communication strategies exist. They can promote knowledge and prompt ameliorative action across multiple scales of decision making [18];
- Healthcare professionals are trusted sources of information; messages they deliver can have great impact, both positive and negative [19]; and
- Actions to reduce negative consequences from getting worse (i.e., mitigation strategies) can be enforced from a "top-down" approach (e.g., government mandates) and/or motivated from the "bottom-up" (e.g., educating individuals). It is clear from the pandemic that top-down strategies are effective in that they can be enforced quickly and with a potential for high uptake of behaviors. However, top-down approaches are often socioeconomically unsustainable for long periods of time and may garner low acceptance depending on political and personal will. Bottom-

up strategies, on the other hand, can take considerable time to enact and require high-quality engagement by local communities, households, and individuals [20]. However, they also tend to emphasize autonomy—people feeling like they originate and control their own behaviors—and are key because they can empower individuals and lead to more effective and lasting behavior change [21]. Thus, establishing a combination of top-down and bottom-up approaches, while assessing their separate and combined effects along the way, may prove best for facilitating climate-change mitigation and healthy behaviors.

In this paper, we highlight eleven communication methods that have received empirical support for improving knowledge uptake and/or driving higher-quality decision making and healthier behaviors at the individual level. We apply and extend these recommendations to inform communication efforts at the intersection of climate and health (see Box 1). Based on past research in other domains, we expect the principles to be effective across communication audiences, whether between healthcare professionals and patients, family and friends, or corporations, governments, organizations, and other stakeholders.

Box 1. Summary of communication recommendations

1. Communications need to come from trusted sources
2. Leveraging social networks is key to shaping who is influenced and how they are influenced
3. Establish and maintain social norms
4. Focus on belonging and empowerment
5. Use subtle, but powerful, language choices
6. Use emotions
7. Use visual images
8. Use narrative communication to bridge the gap between health and climate change
9. Present statistics to drive understanding of risk and motivate climate-friendly and healthier behaviors

10. Identify and reduce barriers to enacting health behaviors
11. Explicitly test messages with your target group

Communication Strategies with Strong Evidence for Improving Health Communication Efforts and Climate Change Outcomes

Recommendation 1: Communications Need to Come From Trusted Sources

How much one trusts the individual or group communicating about a health risk can drive how messages are attended to, processed, and acted upon. Ultimately, messages from trusted sources tend to be more persuasive [22], and people follow recommendations more when they come from a trusted person or group. Of course, climate-change messages (similar to COVID-19 messages) can be politically divisive [23], even when health communication co-occurs. Thus, it may be that getting messages from nonpartisan experts, such as scientists and healthcare professionals, is more likely to promote mitigative and adaptive actions when it comes to climate and health. Indeed, people report that primary care physicians are their most trusted source of information on the health harms of climate change [24]. However, researchers disagree about trust in scientists. Some researchers find that trust in scientists has waned over time, at least among some groups [25]; others argue that the public continues to hold science and scientists in high regard [26]. Nonetheless, experimental evidence highlights that messages from climate scientists concerning climate effects have had no effect or negative effects on public perceptions [27], perhaps because people simply expected such messages from them (although this study did not test climate-related health messages). Getting a climate-effect message from other sources may be more surprising. Consistent with this power of surprise, getting the same climate-effects messages from military leaders was more persuasive [27]. Finally, it is important to understand individuals' values and identities with respect to climate-change-related issues because it affects who they trust and how they use trusted sources to make their choices. For example, environmental-threat messages from Republican Party leaders were more persuasive to Republicans than messages from other sources. In the case of healthcare professionals as communicators, fundamental values and needs for wellbeing [28], combined with

perceiving healthcare professionals as a means to that end, may explain them as trusted sources of all things health-related, including on climate topics. Of course, differences exist even in the trustworthiness of healthcare professionals, and perhaps especially because of history and ongoing experiences of discrimination and structural racism for people of color and marginalized populations [29]. Healthcare professionals who maintain and build trust can have bigger impact.

Recommendation 2: Leveraging Social Networks is Key to Shaping Who is Influenced and How They are Influenced.

Effective communication strategies need to consider simultaneously both social networks (i.e., networks of personal relationships and social interactions) and human social motives (i.e., the process of social influence wherein one person's attitudes and behaviors affect another's) [30]. Doing so enables us to leverage the "who" and the "how" of social influence. Specifically, network research has helped us identify the opinion leaders that shape the attitudes and behaviors of their peers [31-32]. In some cases, the most influential people are those who are seen as domain experts or civic and religious leaders in the community. Thus, healthcare professionals might be the most influential in conversations about health and climate change. In other cases, the most influential are those with whom the individual has close, personal, and trusting relationships such as family and friends. To understand which type of influencer is more effective and how they might deploy that influence, we turn to a second line of research in social psychology [33-34]. Specifically, people have varying social motives that have different underlying causes. The need for accuracy (the need to be "right") and the need for affiliation (the need to be "liked") stimulate attitude and behavior change via mechanisms of compliance and conformity [35]. People with a need for accuracy will be amenable to attitude and behavior change when they receive facts from those they deem to be leaders or experts in their networks. People with a need for affiliation are more likely influenced by those with whom they have close interpersonal network ties. They are more likely to change their own attitudes and behaviors to maintain those relationships rather than be swayed by facts. Thus, healthcare professionals will have more influence over their patients' climate-related healthy behaviors when that patient has a need for accuracy. For patients with a need for affiliation, however,

healthcare professionals might gain more influence if they can convince someone close to the patient to intervene with their message. More research is needed on how healthcare professionals, public-health professionals, and others might be able to change a person's motives from affiliation to accuracy.

Recommendation 3: Establish and Maintain Social Norms.

What people perceive that others are doing or should be doing can guide and direct behaviors; we tend to conform to social norms. As a result, normative social influence can be an effective strategy to promote behavior change [36-37]. Different types of social norms exist and can affect behaviors. *Descriptive norms* delineate prevalence rates in a population (e.g., how often do people do some behavior) whereas *injunctive norms* relate to beliefs about whether a behavior is generally valued or spurned. Individuals given feedback about a descriptive norm—for example, that their household energy use was less than that of other similar households—tended to increase energy use unless that descriptive norm was used in tandem with an injunctive norm indicating that decreased energy use is good [37]. In general, individuals tend to underestimate how much descriptive norms affect their decisions [38]. These effects also can be strengthened by inviting people to work with others toward a common goal (e.g., "Let's do it together") [39]. With injunctive norms about how valued a behavior is, expectations about others' beliefs about climate change are important to consider [40]. Such beliefs paradoxically can lead to an unwillingness to discuss the topic with others if, for example, a belief exists that peers do not care about the topic, a phenomenon known as "pluralistic ignorance" [41].

Both descriptive and injunctive norms also can be dynamic (i.e., malleable and shifting over time). Communicating such *dynamic norms* can be effective in changing behaviors. For example, communicating the injunctive norm that habits such as driving and eating red meat are harmful to the well-being of the planet and one's health can create a dynamic shift in norms, by decreasing widespread acceptance of such unsustainable behaviors [42]. Then, communicating that dynamic norm shift using social networks can drive further decreases in behaviors and their acceptability. It is important to understand the mechanisms underlying large norm shifts necessary for addressing climate change because they may point to needed changes in communications about climate change and health.

Thus, communicators can use descriptive and injunctive norms to facilitate individual behavior change. For example, they could describe the negative impacts of climate change on communities similar to the one in which the targeted individual lives and, then, highlight that many people care about these effects and are affected by them. Further, communicating the worsening impact that climate-change is having on certain vulnerable communities and how more individuals are becoming concerned about this issue can effectively communicate a dynamic norm to facilitate behavior change.

A key area for future research in climate and health emerges from research by Cristina Bicchieri and her colleagues. They demonstrate that communicating norms is less effective when the person's behavior is independent of others [43]. Such independence can occur either because the person believes their behavior meets their own needs (so descriptive norms won't be as effective) or because they believe their behavior is the right thing to do (making injunctive norms less effective). For example, telling an individual that some behavior is common in another group may not mean that they also think it is common in their own group. When using norms, communicators need to identify and specify a relevant reference group to avoid such interpretations, a more difficult task in primarily individualistic societies, such as the United States of America.

Recommendation 4: Values - Focus on Belonging and Empowerment.

Another key strategy is to identify organizations where people have either formal or informal membership and to which they feel like they belong, such as religious communities, civic groups, employers, and professional organizations. These organizations then can deliver messages for greater effect when attempting to empower people with greater understanding of the severe health consequences of climate change. Positive (and negative) effects of organizations communicating messages emerge because organizations teach people norms, values, and behaviors. When these thoughts, feelings, and actions align, people can feel a shared social identity, known as organizational identification [44]. Research in organizational health communication, for example, has found that when people identify more with an organization delivering a health message, they have more positive thoughts and feelings about the message, and they are more likely to be persuaded by it [45]. Furthermore, when people feel like they

belong in an organization that provides them with health information, they are more likely to share this information with others, thus increasing its impact [46]. The positive health effects of organizational identification even extend to online communities, like support groups [47]. Thus, the feelings of connection in online and other groups might offer another avenue to share health-related climate-change messages.

Recommendation 5: Use Subtle, But Powerful, Language Choices.

When trying to motivate people to act, it matters what words we choose to use. For example, Dearing and Lapinski [48] suggested that when working with stakeholders skeptical of climate change, framing messages around health may better facilitate acceptance of recommendations. Sometimes called temporal framing, "considerations of future consequences" [49] provides a powerful cognitive construct with insights into how to motivate people to act in the present when the benefits primarily occur in the future. Empirical work has focused considerably on healthy behaviors [e.g., 50]. However, studies demonstrate that pro-environmental behaviors and future time perspectives are positively related [51], suggesting that this approach is reasonable for climate-health communication. Yet scholars have done little work on how to apply these theories to communication practices that can affect decisions and behavior when articulating the relationship between climate change and health.

Current climate-change communication tends to focus on its long-term impacts (e.g., slowly rising temperatures and sea levels). However, emphasizing nearer-term health benefits of climate-change mitigation behaviors (e.g., improved air pollution with a transition away from fossil fuels) increases perceptions of fossil-fuel harm as well as intentions to engage in consumer advocacy [52]. In fact, emphasizing health benefits can be more effective for issue engagement compared to economic, national security, environmental, morality, and political conflict framing [53] and may be particularly effective among people who are politically moderate and somewhat conservative [54]. Thus, we recommend taking this public health issue-framing approach when communicating climate change and health messages to diverse and large audiences. In general, highlighting or "framing" climate change as a public health issue can make the issues personally relevant [55-56].

In addition to framing, another linguistic strategy that offers promise is referred to as agency assignment; communicators can use verbs to change the focus of causation [57]. This feature of messages is subtle, but prior research in health contexts has found that direct messages (e.g., a virus can harm a person) evoke stronger intentions to take protective actions than more indirect messages such as saying a person could contract a disease caused by the virus [58-59]. Using language to convey that environmental threats can harm people's health could be an important messaging approach to use but needs more experimental tests.

Recommendation 6: Use Emotions.

Health psychological research has a long history of using negative emotions to compel behavior change. From early attempts to scare patients to quit smoking by showing diseased lung tissue to efforts in the eighties to reduce drug use by showing a pan with fried eggs with its now (in)famous tagline "this is your brain on drugs." These fear appeals have had limited success as messages by themselves but are more successful when combined with action plans to increase people's confidence in their ability to act (e.g., provide concrete information about how to quit smoking, avoid drug use, and reduce energy consumption at home) [60].

More recently, the role of affect (defined as good or bad feelings about an object that are generally milder than a full-blown emotion, and are experienced at the moment of judgment or choice) in information processing, decision making, and behavior change has seen greater formalization. We use fast intuitive feelings to determine our judgments and decisions in a wide range of important personal and societal decisions, often without conscious awareness [61]. These feelings seem to precede and determine judgments of risk and benefit. Furthermore, researchers have uncovered evidence for three discrete affect functions that appear to underlie both health communication and decision making: a) affect as information; b) affect as spotlight; and c) affect as motivator [62]. We discuss these functions in turn and provide relevant examples for climate-related processing and behavior change.

First, affect can act as information, substituting for other data-based sources, such as relevant statistics and informing the individual's evaluation of health or environmental threats. For example,

through the workings of the "affect heuristic" [63], people with high levels of negative affect to climate change (e.g., worry, anxiety) may perceive climate change as imminent and catastrophic whereas those with lower levels of negative affect perceive it as an unlikely distant threat not worth their consideration. This affective coloring is often based on individuals' experiences accumulated over their lifespan, but it can also arise in the moment, for example, as a result of visual images and narratives (see Recommendations 7 and 8). Then, conscious or unconscious affective reactions to information can lead to a decreased use of risk-based and statistical information. As a result, if a person feels good about fossil fuels, they will likely perceive its benefits as greater and risks as smaller—despite statistical evidence—than another person who feels bad about them. Communicators also can use affect's function as information strategically, for example, by attaching negative affect to the threat through visual images or verbal or other cues that convey its negativity when a threat is pallid and far off into the future (e.g., increased sea level rise) [64-65].

The second function, "affect as spotlight," follows this quick evaluation and directs the individual to information that often validates an existing feeling. In other words, affect allows the retrieval of similar affectively-coded circumstances. To continue the example above, high negative affect in response to climate change will direct the individual to seek information that confirms the catastrophic nature of climate change; they may also disregard positive developments because it is outside the "spotlight of attention." Over time, repeated exposure to fear-inducing climate-change information can increase the immediacy of the threat, increase the level of negative affect, and might lead to climate-related actions and particularly if people believe their actions can make a difference [60]. However, communicators may need to draw attention to positive developments to maintain hope, confidence, and continued action [66].

Affect as a motivator is the third, most well-known function. Negative affect, such as worry and anxiety, can motivate health actions such as cancer screening, especially when a clear action plan is given [67]. Attaching positive and negative affect to choice options through the use of verbal evaluative labels also can alter choices, perhaps especially when the options are perceived as abstract and meaningless as they sometimes are in health [65]. It may also motivate climate-related actions. For example, rising sea

levels and people's migratory patterns in the next decade may be perceived as far off in the future. Visually simulating them and their potential outcomes may motivate more information seeking (affect as spotlight) and/or motivate people to behave differently including by demanding action from the government (affect as motivator) [see, e.g., 68].

In summary, affect is a powerful influence on decision making and health behavior change. Affect determines a quick evaluation of a situation as good or bad, it directs further information seeking, often to confirm the initial evaluation of the situation, and it is capable of both motivating and limiting action. The functions do not need to occur sequentially as described, but can also occur simultaneously.

Recommendation 7: Use Visual Images.

Visual images (e.g., pictures conveying the health harms of smoking or animations depicting changes to the heart with heart disease) can be highly effective communication tools. Images and text-based or verbal information can differentially influence concern and motivate protective action, primarily because they are processed in distinct cognitive systems [63, 69]. Text and verbal information are processed within an abstract, conceptual system of reasoned and linguistic processes whereas images are processed within a concrete-experiential system that is relatively non-analytic and encodes experiences as images and perceptual memories. Multiple mechanisms, distinct to the concrete-experiential system, contribute to the persuasive potency of visual images in communications.

First, visual images are superior to text or verbal information in attracting attention [70]. Visual images capture and direct attention, thereby serving as an entry point into the communication. This attentional advantage is particularly strong when a communication induces fear-related reactions. Fear arousal activates the visual-spatial regions of the brain and enhances vigilance in attention to visual-spatial information about the threat [71]. These processes induce richer encoding and memory of the images [72]. Images are also processed more rapidly than linguistic information, and they evoke mental experiences that are close to the perceptual reality of those experiences [73-74]. As such, they are readily accepted as credible and valid depictions of reality. Using images depicting concrete environmental

damage and health harms of climate change in communications could enhance the acceptance of this information by those who are skeptical of its validity.

Furthermore, images, relative to words, can induce stronger emotional responses [75-76] that can fuel risk perceptions, concern, and motivations to take protective action. Images can do so by instilling more affective meaning about the issue, which leads people to internalize the information as personally relevant and important [77-78]. As one example in the health domain, pictorial warnings for cigarettes are more effective than text warnings in arousing worry, discouraging smoking, and increasing quit attempts [64, 79-82]. In the environmental domain, images of pollution (e.g., smokestacks billowing out black smoke) and natural disasters linked with climate change (e.g., wildfires) evoke fear and anger which, in turn, may motivate actions such as endorsement of climate change policies and energy conservation [78, 83-84]. Images eliciting positive emotions can also be impactful. Images depicting actions to mitigate climate change (e.g., solar panels) can promote positive emotions and hope which, in turn, promote actions to mitigate climate change [53, 78, 83].

Communications that use visual images to promote a coherent understanding of the links between risk status, protective behavior, and health outcomes have been shown to enhance protective motivations and behavior change [85-86], suggesting that images could be highly efficient and effective in instilling a coherent understanding of the abstract and complex associations between climate change and health. Environmental threats themselves can be difficult to understand because they tend to be “invisible”, complex, distant, and hard to imagine [87]. Further, their direct and indirect health connections can be insidious, complex, and abstract. For example, it can be difficult to grasp information that higher pollen levels caused by warmer temperatures make asthma worse when it is presented solely in an abstract, text-based format. Communications that incorporate images can aid in overcoming this sense of invisibility and abstractness, enhancing understanding of environmental and health risks, and motivating action.

Images also can be used to enhance perceived efficacy to take actions that contribute meaningfully to climate change mitigation and disease control. This potential is important given the growing evidence that efficacy perceptions are resistant to change via verbal or text communications that

target explicit, deliberative reasoning processes; rather, efficacy beliefs are shifted more through non-analytic, experiential, and image-based processes [88]. For example, images of people taking pro-environmental actions (e.g., protesting, walking or riding bikes, choosing "green" products at the store) may enhance efficacy beliefs by conveying that many others also are able to engage in those actions [89].

Finally, visual images can out-perform text-based information in communications because they are generally easier to remember [72-73], and, when emotional, they make associated information more memorable over time [90-91]. Images can instill vivid mental images that are highly accessible and, when activated, have strong and typically automatic, non-deliberative influences on behavior motivations [74]. In the health domain, images are recalled more readily and, relative to text information, induce greater changes in protective behaviors [85, 92]. In the environmental domain, threat images (e.g., ocean plastic pollution) instill rich mental images that are recalled better than comparable information from text-based messages. Further, these mental images enhance the formation of pro-environmental goals and behavior change [93].

Although visual images can be powerful communication tools for promoting persuasion and protective action, they must be selected with care and after adequate testing with members of the target audience. Images selected by intuition alone can be ineffective and even backfire. For example, using abstract and distal images conveying the "global" nature of climate change and its health consequences can make the issue seem less personally relevant and reduce the message's impact on behavior and policy endorsement [94]. Images that are decontextualized and seemingly dissociated from accompanying text messages can also undermine persuasiveness and, in turn, behavior change [93, 95]. Communicators should avoid using images that are not clearly relevant to the primary communication aims, as they will detract attention and recall away from the critical points [96].

Recommendation 8: Use Narrative Communication to Bridge the Gap Between Health and Climate Change

Similar to traditional health communication, climate-change communication largely employs rhetorical arguments focused on promoting awareness and increasing knowledge, often through the

presentation of statistical evidence (e.g., probabilities, graphs) and facts (e.g., temperatures are rising, hurricanes becoming more intense) [97]. Although facts are important components of both health and climate change communication and especially when communicated in an evidence-based manner, transferring knowledge and raising awareness can be insufficient to motivate behavior change. Further, evidence suggests that climate-change beliefs are heavily influenced by cultural values and worldviews rather than factual knowledge [98-99]. Moreover, a disconnect often exists between the information presented (in both climate-change- and health-communication domains) and the relevance of this information within a person's own life [100]. Health-focused narratives can increase perceptions of this relevance and have effects on emotions, beliefs, attitudes, and behavior change intentions, making them a potentially useful tool [see, e.g., 101]. Further, evidence suggests that narratives can shape an individual's comprehension, preferences, and opinions about climate change and promote behavior change [99, 102-103]. Thus, narrative communication, one of the most basic forms of human interaction, may be particularly suited to bridging the gap between health information, climate change, and how they relate to one's personal life.

Narratives are stories describing fictional or true-life experiences that address social issues or political events, told in a chronological sequence of events, with a persuasive element that is implicitly embedded within the story [103-105]. Instead of presenting a series of logical arguments, narratives engage the audience with fictional or real-life experiences that are difficult to dispute [106]. During a narrative, an individual can be "transported" into another person's experiences, and for a short time, the receiver is absorbed within the story [107-108]. A "transported" individual is more likely to believe the experiences of the narrator and therefore is less likely to dispute information presented in the story [105]. By reducing this cognitive resistance in the audience, a narrative can change attitudes and increase self-efficacy, intentions, and behaviors [109]. The perception that the story is similar to the real world increases the transportation of the audience [110]. Other factors moderate the effectiveness of the narrative message, such as the extent of involvement in the story plot, how relevant or relatable the message is to the audience's own life, how immersed one is with the story, and how concentrated is the

message receiver. Additionally, identifying with the characters (i.e., having similar goals and perspectives) and developing emotions for the characters creates a greater influence of their perspective on the beliefs of the audience and has been shown to increase knowledge and shift attitudes, beliefs, and behaviors [111].

Narrative storytelling has power in delivering information related to climate change and, independently, to health [see, e.g., 112-115]. Its effectiveness as a tool to modify beliefs and behaviors at the intersection of climate change and health has not been examined but may be particularly valuable in communicating information and motivating health behavior and climate change mitigating actions.

To this end, we suggest important elements to include within narratives communicating health-behavior change and climate-change mitigation. These narratives should define the problem (e.g., climate change and its impact on health), indicate the causes (e.g., burning of fossil fuels), and discuss the potential solutions (e.g., transitioning away from fossil fuels to renewable energy) and moral responsibilities (e.g., certain populations disproportionately bear the health burdens; those who contributed the least to climate change suffer the most) [116-117]. Because other societal stakeholders can put forward impactful but opposing narratives, narratives also should help build understanding of the scientific process and scientific reasoning to counteract such opposing narratives [118]. Further, Tàbara and colleagues [119] have recommended using transformative narratives, which tell a positive and engaging story, that convey a future vision, and provide solutions and strategies for attaining this vision.

Recommendation 9: Present Statistics to Drive Understanding of Risk and Motivate Climate-Friendly and Healthier Behaviors.

Providing people with climate-related health statistics may educate and motivate. However, many people lack basic numeric skills. For example, about a third of American adults are considered innumerate [120]. As a result, numbers might confuse rather than inform [121]. Nonetheless, providing numbers can help correct false facts and misinterpretations while avoiding surprise, regret, and anger when the unexpected occurs. Because people also prefer getting statistics and perceive them as useful [122-123] providing statistics will help earn the public's trust and build healthier behaviors [124]. In fact,

providing numbers matters for health decisions. In one study, participants read about a drug prescribed to treat high cholesterol [125]. Participants read about its side effects and were randomly assigned to see side-effect likelihoods in non-numeric form (e.g., headaches are common) or numeric form (seven percent get headaches). Most non-numeric participants overestimated its risk whereas numeric participants more accurately understood their chances of experiencing side effects and were more willing to follow doctor recommendations. Findings held for those higher and lower in numeric ability. In a climate-related study, participants again were randomly assigned to receive numeric or nonnumeric information about the scientific consensus concerning human-caused climate change [126]. When provided the correct statistics, participants across political ideologies became more accurate and confident about the consensus. Hart [127] also demonstrated that less numerate participants presented with a numeric description of the impact of climate change on polar bears were more worried and concerned for polar bears than those presented with a nonnumeric description; the same effect did not hold for the highly numerate.

Current methods of presenting statistics, however, are often too difficult for the public who need communicators to provide simple, easy-to-understand, and appropriate comparisons. Visual data displays can promote comprehension [128], but designing them is difficult, and can lead to worse comprehension [129]. When presenting numbers to patients or the public, communicators should first identify a communication goal(s) by ascertaining what the individual should get out of the communication and then by selecting information and information displays that allow these goals to be met. With an established communication goal, the communicator then can decide how to present the data relevant to that goal.

Three key points exist for effective information displays – reduce cognitive effort, increase information meaning, and draw attention to important information [130]. First, when a communication requires less cognitive effort from people, they understand more. Messages should include only the key information and most relevant options rather than all the information. Communicators also should do any math for their audiences. For example, rather than informing people about the risk of climate-related flooding this year, messages should convey the risk for a longer period relevant to how long they can see themselves living in the area. In the COVID-19 pandemic, telling people the number of infectious cases in

their area has been common. However, after identifying the communication goal was to help people understand the risks of going to a 100-person wedding, the communicator instead could calculate that cumulative risk, telling them, for example, how likely it is that at least one COVID-positive person would be present at a wedding of that size. Second, people will sometimes understand what a number is (e.g., 9% risk), but not how it feels (its good/bad affective meaning) or what it means for them. This difference is particularly prevalent in unfamiliar situations. The meaning of numeric information should also be conveyed in such cases, telling people that the 9% risk means it is very high or quite uncommon, or using a frequency format (9 people out of 100) rather than the percentage format, or providing comparisons so people can figure out the meaning of the numbers on their own [126,130]. Finally, when people ignore important information, communicators can draw attention to it by mentioning it first or last or by emphasizing it (e.g., on paper, its font can be made bigger or bolder). Providing the right facts is important but not enough. Communicators also need to provide them in comprehensible and easy-to-evaluate ways so that the information can be understood and used by decisionmakers. Doing so also can reduce the effects of prior miscommunication or misinformation [125].

Recommendation 10: Identify and Reduce Barriers.

Behaviors are determined by how much they are valued balanced against barriers to performing them. Reducing those barriers can help people increase their healthy and climate-friendly behaviors. For example, as mentioned earlier, providing concrete action plans (e.g., about smoking cessation) can help communications have greater impact as people are motivated by the message AND they know what to do. In the Pacific Northwest, COVID-19 has had the unexpected benefit of helping people get used to purchasing and wearing face masks, an important barrier reduction during recent wildfires that produced toxic air. Other research identifies perceptions of high costs and/or low benefits as barriers. Connecting climate-change behaviors with lower concrete personal or local costs or higher concrete benefits increases the likelihood that people will engage in climate-friendly behaviors [131-132]. For example, people are more likely to eat less red meat for climate reasons when they consider that it also improves their health. Similarly, active transportation (e.g., biking, scooters) is more likely to be adopted when communicators

advocate individual health benefits. Furthermore, focusing on such sustainable behaviors can affect healthy behaviors at the individual level and also boost climate policy support [133].

Recommendation 11: Explicitly Test Messages with Your Target Group.

Involving stakeholders in crafting messages likely will lead to messages that resonate better, leading to greater comprehension of key concepts and healthier, climate-friendly behaviors. Communications also should be tested explicitly for their impact on comprehension, affect and emotions, thoughts, risk and benefit perceptions, and, ultimately, behaviors prior to their use. Such research should be conducted in appropriate populations that vary in their political ideology and particularly in vulnerable populations who are likely to be or should be affected by the communication. If no budget exists for testing, experts at least should prioritize information from most to least important and identify gaps in the target audience's understanding. A good alternative to focus groups are one-on-one interviews with people similar to the intended target audience, for example in terms of levels of education, knowledge, and experience. With more budget, testing messages against one another, such as in messaging experiments or a clinical trial, is crucial to identify those messages likely to produce the best outcomes.

Conclusions

Given that researchers have conducted limited studies about communication at the intersection of climate change and health, an enormous opportunity exists to rapidly advance this knowledge. Current evidence about effective communication strategies from related domains can guide initial communication attempts. Consideration of other aspects of the architecture of health decisions also may point towards ways to stimulate the ultimate effectiveness of communications [134]. For example, nudges at the point-of-purchase that make healthy, environmentally-friendly options easier to access may increase choices of them, thus boosting the impact of earlier convincing communications. Meanwhile, further research should rapidly examine the unique aspects of climate change and health to arrive at the most effective communication strategies – with potentially transformational results [135].

References

1. IPCC. (2014). *Climate Change 2014: Synthesis Report*. In Core Writing Team, R. K. Pachauri & L. A. Meyer (Eds.), Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://www.ipcc.ch/site/assets/uploads/2018/02/SYR_AR5_FINAL_full.pdf

2. Haines, A., & Ebi, K. (2019). The imperative for climate action to protect health. *The New England Journal of Medicine, 380*(3), 263–273. https://doi.org/10.1056/NEJMra1807873

3. IPCC. (2021). *Climate Change 2021: The Physical Science Basis*. In V. Masson-Delmotte, P. Zhai, A. Pirani, S. L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M. I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J. B. R. Matthews, T. K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, & B. Zhou (Eds.), Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. https://www.ipcc.ch/assessment-report/ar6/

4. Salas, R. N., Lester, P. K., & Hess, J. J. (2021). *2021 Lancet Countdown on Health and Climate Change Policy Brief for the United States of America*. Countdown U.S. Policy Brief. https://www.lancetcountdownus.org/wp-content/uploads/2021/10/USA-2021-English-Lancet-Countdown-Policy-Brief.pdf

5. Shindell, D., Ru, M., Zhang, Y., Seltzer, K., Faluvegi, G., Nazarenko, L., Schmidt, G. A., Parsons, L., Challapalli, A., Yang, L., & Glick, A. (2021). Temporal and spatial distribution of health, labor, and crop benefits of climate change mitigation in the United States, *Proceedings of the National Academy of Sciences, 118*(46), e2104061118. https://doi.org/10.1073/pnas.2104061118.

6. Scovronick, N., Budolfson, M., Dennig, F., Errickson, F., Fleurbaey, M., Peng, W., Socolow, R. H., Spears, D., & Wagner, F. (2019). The impact of human health co-benefits on evaluations of global climate policy. *Nature Communications*, *10*, 1–12. https://doi.org/10.1038/s41467-019-09499-x

7. Vandyck, T., Keramidas, K., Kitous, A., Spadaro, J. V., Van Dingenen, R., Holland, M., & Saveyn, B. (2018). Air quality co-benefits for human health and agriculture counterbalance costs to meet Paris Agreement pledges. *Nature Communications, 9*(1), 4939. https://doi.org/10.1038/s41467-018-06885-9

8. Smith, K. R., Woodward, A., Campbell-Lendrum, D., Chadee, D. D., Honda, Y., Liu, Q., Olwoch, J. M., Revich, B., & Sauerborn, R. (2014). Human health: Impacts, adaptation, and co-benefits. In C. B. Field, V. R. Barros, D. J. Dokken, K. J. Mach, M. D. Mastrandrea, T. E. Bilir, M. Chatterjee, K. L. Ebi, Y. O. Estrada, R. C. Genova, B. Girma, E. S. Kissel, A. N. Levy, S. MacCracken, P. R. Mastrandrea, & L. L. White (Eds.), *Climate Change 2014: Impacts, Adaptation, and Vulnerability*. (pp. 709-754). Cambridge University Press, Cambridge, United Kingdom and New York, NY.

9. Zhang, Y., Smith, S.J., Bowden, J.H., Adelman, Z., & West J.J. (2017). Co-benefits of global, domestic, and sectoral greenhouse gas mitigation for US air quality and human health in 2050. *Environmental Research Letter, 12,*114033.

10. Romanello, M., McGushin, A., Di Napoli, C., Drummond, P., Hughes, N., Jamart, L., Kennard, H., Lampard, P., Solano Rodriguez, B., Arnell, N., Ayeb-Karlsson, S., Belesova, K., Cai, W., Campbell-Lendrum, D., Capstick, S., Chambers, J., Chu, L., Ciampi, L., Dalin, C., Dasandi, N., … Hamilton, I. (2021). The 2021 report of the Lancet Countdown on health and climate change: Code red for a healthy future. *Lancet, 398*(10311), 1619–1662. https://doi.org/10.1016/S0140-6736(21)01787-6

11. Salas, R. N., & Solomon, C. G. (2019). The climate crisis - health and care delivery. *The New England Journal of Medicine, 38*1(8), e13. https://doi.org/10.1056/NEJMp1906035

12. Orlove, B., Shwom, R., Markowitz, E., & Cheong, S. M. (2020). Climate decision-making. *Annual Review of Environment and Resources, 45*(1), 271-303. https://doi.org/10.1146/annurev-environ-012320-085130

13. Salas R. N. (2021). Environmental racism and climate change - missed diagnoses. *The New England Journal of Medicine, 385*(11), 967–969. https://doi.org/10.1056/NEJMp2109160

14. Mendoza-Vasconez, McLaughlin E., Sallis J.F., Maibach E., Epel, E., Bennett, G., Nogueira, L., Thayer, J., & Dietz, W.H. (2022). Advocacy to support climate and health policies: Recommended Actions for the Society of Behavioral Medicine. *Translational Behavioral Medicine.*

15. Simis, M. J., Madden, H., Cacciatore, M. A., & Yeo, S. K. (2016). The lure of rationality: Why does the deficit model persist in science communication? *Public Understanding of Science, 25*(4), 400–414. https://doi.org/10.1177/0963662516629749

16. Kumar, A., Malla, M. A., & Dubey, A. (2020). With corona outbreak: Nature started hitting the reset button globally. *Frontiers in Public Health, 8*, 569353. https://doi.org/10.3389/fpubh.2020.569353

17. Rume, T., & Islam, S. (2020). Environmental effects of COVID-19 pandemic and potential strategies of sustainability. *Heliyon, 6*(9), e04965. https://doi.org/10.1016/j.heliyon.2020.e04965

18. National Research Council. (2020). Encouraging adoption of protective behaviors to mitigate the spread of COVID-19: Strategies for behavior change. *The National Academies Press*. https://doi.org/10.17226/25881

19. Torres, C., Ogbu-Nwobodo, L., Alsan, M., Stanford, F. C., Banerjee, A., Breza, E., Chandrasekhar, A. G., Eichmeyer, S., Karnani, M., Loisel, T., Goldsmith-Pinkham, P., Olken, B. A., Vautrey, P. L., Warner, E., Duflo, E., & COVID-19 Working Group (2021). Effect of physician-delivered COVID-19 public health messages and messages acknowledging racial inequity on Black and White adults' knowledge, beliefs, and practices related to COVID-19: A randomized clinical trial. *JAMA Network Open, 4*(7), e2117115. https://doi.org/10.1001/jamanetworkopen.2021.17115

20. Jalloh, M. F., Nur, A. A., Nur, S. A., Winters, M., Bedson, J., Pedi, D., Prybylski, D., Namageyo-Funa, A., Hageman, K. M., Baker, B. J., Jalloh, M. B., Eng, E., Nordenstedt, H., & Hakim, A. J.

(2021). Behaviour adoption approaches during public health emergencies: Implications for the COVID-19 pandemic and beyond. *BMJ Global Health*, 6(1), e004450. https://doi.org/10.1136/bmjgh-2020-004450

21. Ng, J. Y. Y., Ntoumanis, N., Thøgersen-Ntoumani, C., Deci, E. L., Ryan, R. M., Duda, J. L., & Williams, G. C. (2012). Self-Determination Theory applied to health contexts: A meta-analysis. *Perspectives on Psychological Science, 7*(4), 325–340. https://doi.org/10.1177/1745691612447309

22. Pornpitakpan, C. (2004). The persuasiveness of source credibility: A critical review of five decades' evidence. *Journal of Applied Social Psychology, 34*(2), 243–281. https://doi.org/10.1111/j.1559-1816.2004.tb02547.x

23. Jasny, L., Waggle, J., & Fisher, D. R. (2015). An empirical examination of echo chambers in US climate policy networks. *Nature Climate Change, 5*, 782-786. https://doi.org/10.1038/nclimate2666

24. Roser-Renouf, C., & Maibach E. W. (2018). Strategic communication research to illuminate and promote public engagement with climate change. In: D. Hope & R. Bevin (Eds.), *Change and Maintaining Change*. Nebraska Symposium on Motivation, vol 65. Springer, Cham. https://doi.org/10.1007/978-3-319-96920-6_6

25. Hmielowski, J. D., Feldman, L., Myers, T. A., Leiserowitz, A., & Maibach, E. (2014). An attack on science? Media use, trust in scientists, and perceptions of global warming. *Public Understanding of Science, 23*(7), 866-883. https://doi.org/10.1177/0963662513480091

26. Leshner, A. I. (2021). Trust in science is not the problem. *Issues in Science and Technology, 37*(3). https://issues.org/trust-in-science-is-not-the-problem-engagement-leshner/

27. Bolsen, T., Palm, R., & Kingsland, J. T. (2019). The impact of message source on the effectiveness of communications about climate change. *Science Communication, 41*(4), 464–487. https://doi.org/10.1177/1075547019863154

28. Deci, E. L., & Ryan, R. M. (2000) The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*(4), 227-268. https://doi.org/10.1207/S15327965PLI1104_01

29. Egede, L. E., & Walker, R. J. (2020). Structural racism, social risk factors, and Covid-19 — A dangerous convergence for Black Americans. *New England Journal of Medicine, 383*(12), e77. https://doi.org/10.1056/NEJMp2023616

30. Contractor, N. S., & DeChurch, L. A. (2014). Integrating social networks and human social motives to achieve social influence at scale. *Proceedings of the National Academy of Sciences, 111*(Supplement 4), 13650-13657. https://doi.org/10.1073/pnas.1401211111

31. Friedkin, N. (1998). A Structural Theory of Social Influence. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511527524

32. Friedkin, N. E., Proskurnikov, A. V., Tempo, R., & Parsegov, S. E. (2016). Network science on belief system dynamics under logic constraints. *Science, 354*(6310), 321–326. https://doi.org/10.1126/science.aag2624

33. Cialdini, R. B. (2001). The science of persuasion. *Scientific American, 284*(2), 76–81. https://doi.org/10.1038/SCIENTIFICAMERICAN0201-76

34. Cialdini, R. B. (2003). Crafting normative messages to protect the environment. *Current Directions in Psychological Science, 12*(4), 105–109. https://doi.org/10.1111/1467-8721.01242

35. Cialdini, R. B., & Goldstein, N. J. (2004). Social influence: Compliance and conformity. *Annual Review of Psychology, 55*, 591–621. https://doi.org/10.1146/annurev.psych.55.090902.142015

36. Schultz, P. W., Khazian, A. M., & Zaleski, A. C. (2008). Using normative social influence to promote conservation among hotel guests. *Social Influence, 3*(1), 4–23. https://doi.org/10.1080/15534510701755614

37. Schultz, P. W., Nolan, J. M., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2007). The constructive, destructive, and reconstructive power of social norms. *Psychological Science, 18*(5), 429–434. https://doi.org/10.1111/j.1467-9280.2007.01917.x

38. Nolan, J. M., Schultz, P. W., Cialdini, R. B., Goldstein, N. J., & Griskevicius, V. (2008). Normative Social Influence is Underdetected. *Personality and Social Psychology Bulletin, 34*(7), 913–923. https://doi.org/10.1177/0146167208316691

39. Howe, L. C., Carr, P. B., & Walton, G. M. (2021). Normative appeals motivate people to contribute to collective action problems more when they invite people to work together toward a common goal. *Journal of Personality and Social Psychology, 121*(2), 215–238. https://doi.org/10.1037/pspa0000278

40. Nolan J. M. (2021). Social norm interventions as a tool for pro-climate change. *Current Opinion in Psychology*, *42*, 120–125. Advance online publication. https://doi.org/10.1016/j.copsyc.2021.06.001

41. Geiger, N., & Swim, J. K. (2016). Climate of silence: Pluralistic ignorance as a barrier to climate change discussion. *Journal of Environmental Psychology, 47*, 79–90. https://doi.org/10.1016/j.jenvp.2016.05.002

42. Sparkman, G., Howe, L., & Walton, G. (2021). How social norms are often a barrier to addressing climate change but can be part of the solution. *Behavioural Public Policy, 5*(4), 528-555. doi:10.1017/bpp.2020.42

43. Bicchieri, C., & Dimant, E. (2019). Nudging with care: The risks and benefits of social information. *Public Choice*. https://doi.org/10.1007/s11127-019-00684-6

44. Dutton, J. E., Dukerich, J. M., & Harquail, C. V. (1994). Organizational images and member identification. *Administrative Science Quarterly*, *39*(2), 293-363. https://doi.org/10.2307/2393235

45. Stephens, K. K., Goins, E. S., & Dailey, S. L. (2014). Organizations disseminating health messages: The roles of organizational identification and HITs. *Health Communication*, *29*(4), 398-409. https://doi.org/10.1080/10410236.2012.759896

46. Crook, B., Stephens, K. K., Pastorek, A. E., Mackert, M., & Donovan, E. E. (2016). Sharing health information and influencing behavioral intentions: The role of health literacy, information

overload, and the internet in the diffusion of healthy heart information. *Health Communication, 31*(1), 60-71. https://doi.org/10.1080/10410236.2014.936336

47. Zhu, Y., & Stephens, K. K. (2019). Online support group participation and social support: Incorporating identification and interpersonal bonds. *Small Group Research, 50*(5), 593–622. https://doi.org/10.1177/1046496419861743 2019

48. Dearing, J. W., & Lapinski, M. (2020). Multisolving innovations for climate and health: Message framing to achieve broad public support. *Health Affairs, 39*(12), 2175-2181. https://doi.org/10.1377/hlthaff.2020.01170

49. Strathman, A., Gleicher, F., Boninger, D. S., & Edwards, C. S. (1994). The consideration of future consequences: Weighing immediate and distant outcomes of behavior. *Journal of Personality and Social Psychology, 66*(4), 742-752. https://doi.org/10.1037/0022-3514.66.4.742

50. Murphy, L., & Dockray, S. (2018). The consideration of future consequences and health behaviour: A metaanalysis. *Health Psychology Review, 12*(4), 357-381. https://doi.org/10.1080/17437199.2018.1489298

51. Milfont, T., Wilson, J., & Diniz, P. (2012). Time perspective and environmental engagement: A meta-analysis. *International Journal of Psychology, 47*(5), 325-334. https://doi.org/10.1080/00207594.2011.647029

52. Kotcher, J., Maibach, E., & Choi, W. T. (2019). Fossil fuels are harming our brains: identifying key messages about the health effects of air pollution from fossil fuels. *BMC Public Health, 19*(1), 1079. https://doi.org/10.1186/s12889-019-7373-1

53. Feldman, L., & Hart, P. S. (2018). Is there any hope? How climate change news imagery and text influence audience emotions and support for climate mitigation policies. *Risk Analysis, 38*(3), 585-602. https://doi.org/10.1111/risa.12868

54. Kotcher, J., Maibach, E., Montoro, M., & Hassol, S. J. (2018). How Americans respond to information about global warming's health impacts: Evidence from a national survey experiment. *GeoHealth, 2*(9), 262–275. https://doi.org/10.1029/2018GH000154

55. Maibach, E. W., Leiserowitz, A., Roser-Renouf, C., & Mertz, C. K. (2011). Identifying like-minded audiences for global warming public engagement campaigns: An audience segmentation analysis and tool development. *PLOS ONE 6*(3): e17571. https://doi.org/10.1371/journal.pone.0017571

56. Weathers, M. R., Mosher, M. M. & Maibach, E. (2020). Communicating the public health implications of climate change. In D. C. Holmes & L. M. Richardson (Eds), *Research Handbook on Communicating Climate Change*. (pp. 259-261). Edward Elgar Publishing, Inc., Northampton, MA. https://doi.org/10.4337/9781789900408.00038

57. Dowty, D. (1991). Thematic proto-roles and argument selection. *Language, 67*(3), 547–619. https://doi.org/10.1353/lan.1991.0021

58. McGlone, M. S., Bell, R. A., Zaitchik, S. T., & McGlynn, J. (2013). Don't let the flu catch you: Agency assignment in printed educational materials about the H1N1 influenza virus. *Journal of Health Communication, 18*(6), 740–56. https://doi.org/10.1080/10810730.2012.727950

59. McGlone, M. S., Stephens, K. K., Gonzalez, S., & Fernandez, M. (2017). Persuasive texts for prompting action: Agency assignment in HPV vaccination text message reminders. *Vaccine, 35*(34), 4295 – 4297. https://doi.org/10.1016/j.vaccine.2017.06.080

60. Witte, K., & Allen, M. (2000). A meta-analysis of fear appeals: Implications for effective public health campaigns. *Health Education & Behavior, 27*(5), 591–615. https://doi.org/10.1177/109019810002700506

61. Slovic, P., & Peters, E. (2006). Risk perception and affect. *Current Directions in Psychological Science, 15*(6), 322–325. https://doi.org/10.1111/j.1467-8721.2006.00461.x

62. Peters, E., Lipkus, I., & Diefenbach, M. A. (2006). The functions of affect in health communications and in the construction of health preferences. *Journal of Communication, 56*(Suppl 1), S140–S162. https://doi.org/10.1111/j.1460-2466.2006.00287.x

63. Slovic, P., Finucane, M. L., Peters, E., & MacGregor, D. G. (2004). Risk as analysis and risk as feelings: Some thoughts about affect, reason, risk, and rationality. *Risk Analysis, 24*(2), 311–322. https://doi.org/10.1111/j.0272-4332.2004.00433.x

64. Evans, A. T., Peters, E., Strasser, A. A., Emery, L. F., Sheerin, K., & Romer, D. (2015). Graphic warning labels elicit affective and thoughtful responses from smokers: Results of a Randomized Clinical Trial. *PLoS ONE, 10*(12), e0142879. https://doi.org/10.1371/journal.pone.0142879

65. Peters, E., Dieckmann, N. F., Västfjäll, D., Mertz, C. K., Slovic, P., & Hibbard, J. H. (2009). Bringing meaning to numbers: The impact of evaluative categories on decisions. *Journal of Experimental Psychology: Applied*, *15*(3), 213–227. https://doi.org/10.1037/a0016978

66. Marlon, J. R., Bloodhart, B., Ballew, M. T., Rolfe-Redding, J., Roser-Renouf, C., Leiserowitz, A., & Maibach, E. (2019). How hope and doubt affect climate change mobilization. *Frontiers in Communication, 4*. https://doi.org/10.3389/fcomm.2019.00020

67. Diefenbach, M. A., Miller, S. M., & Daly, M. B. (1999). Specific worry about breast cancer predicts mammography use in women at risk for breast and ovarian cancer. *Health Psychology, 18*(5), 532–536. https://doi.org/10.1037//0278-6133.18.5.532

68. Jamieson, K. H., & Hardy, B. W. (2014). Leveraging scientific credibility about Arctic Sea ice trends in a polarized political environment. *Proceedings of the National Academy of Sciences of the United States of America, 111 Suppl 4*(Suppl 4), 13598–13605. https://doi.org/10.1073/pnas.1320868111

69. Epstein, S. (1994). Integration of the cognitive and the psychodynamic unconscious. *American Psychologist, 49*(8), 709-724. https://doi.org/10.1037/0003-066X.49.8.709

70. Bucher, H. J., & Schumacher, P. (2005). The relevance of attention for selecting news content: An eye-tracking study on attention patterns in the reception of print and online media. *Communications, 31*, 347-368. https://doi.org/10.1515/COMMUN.2006.022

71. Shackman, A. J., Sarinopoulos, I., Maxwell, J. S., Pizzagalli, D. A., Lavric, A., & Davidson, R. J. (2006). Anxiety selectively disrupts visuospatial working memory. *Emotion, 6*(1), 40–61. https://doi.org/10.1037/1528-3542.6.1.40

72. Putman, P., van Honk, J., Kessels, R. P. C., Mulder, M., & Koppeschaar, H. P. K. (2004). Salivary cortisol and short and long-term memory for emotional faces in healthy young women. *Psychoneuroendocrinology, 29*(7), 953–960. https://doi.org/10.1016/j.psyneuen.2003.09.001

73. Paivio, A., Walsh, M., & Bons, T. (1994). Concreteness effects on memory: When and why? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20*(5), 1196-1204. https://doi.org/10.1037/0278-7393.20.5.1196

74. Stacy, A. W., Ames, S. L., & Knowlton, B. J. (2004). Neurologically plausible distinctions in cognition relevant to drug use etiology and prevention. *Substance Use and Misuse, 39*(10-12), 1571–1623. https://doi.org/10.1081/ja-200033204

75. Holmes, E. A., & Mathews, A. (2005). Mental imagery and emotion: A special relationship? *Emotion, 5*(4), 489–497. https://doi.org/10.1037/1528-3542.5.4.489

76. Schwartz, G. E., Weinberger, D. A., & Singer, J. A. (1981). Cardiovascular differentiation of happiness, sadness, anger, and fear following imagery and exercise. *Psychosomatic Medicine, 43*(4), 343–364. https://doi.org/10.1097/00006842-198108000-00007

77. Smith, N., & Leiserowitz, A. (2012). The rise of global warming skepticism: Exploring affective image associations in the United States over time. *Risk Analysis, 32*(6), 1021–1032. https://doi.org/10.1111/j.1539-6924.2012.01801.x

78. Smith, N., & Leiserowitz, A. (2014). The role of emotion in global warming policy support and opposition. *Risk Analysis, 34*(5), 938-948. https://doi.org/10.1111/risa.12140

79. Magnan, R. E., & Cameron, L. D. (2015). Do young adults perceive that cigarette graphic warnings provide new knowledge about the harms of smoking? *Annals of Behavioral Medicine, 49*(4), 594–604. https://doi.org/10.1007/s12160-015-9691-6

80. Hammond, D., Fong, G., McDonald, P. W., Brown, S., & Cameron, R. (2004). Graphic Canadian cigarette warning labels and adverse outcomes: Evidence from Canadian smokers. *American Journal of Public Health, 94*(8), 1442-1445. https://doi.org/10.2105/ajph.94.8.1442

81. Noar, S. M., Hall, M. G., Francis, D. B, Ribisl, K. M, Pepper, J. K., & Brewer, N. T. (2016). Pictorial cigarette pack warnings: A meta-analysis of experimental studies. *Tobacco Control, 25*(3), 341–354. https://doi.org/10.1136/tobaccocontrol-2014-051978

82. Brewer, N. T., Hall, M. G., Noar, S. M., Parada, H., Stein-Seroussi, A., Bach, L. E., Hanley, S., & Ribisl, K. M. (2016). Effect of pictorial cigarette pack warnings on changes in smoking behavior: A randomized clinical trial. *JAMA Internal Medicine, 176*(7), 905–912. https://doi.org/10.1001/jamainternmed.2016.2621

83. Leviston, Z., Price, J., & Bishop, B. (2014). Imagining climate change: The role of implicit associations and affective psychological distancing in climate change responses. *European Journal of Social Psychology, 44*(5), 441-454. https://doi.org/10.1002/ejsp.2050

84. O'Neill, S. J., Boykoff, M., Niemeyer, S., & Day, S. A. (2013). On the use of imagery for climate change engagement. *Global Environmental Change, 23*(2), 413-421. https://doi.org/10.1016/j.gloenvcha.2012.11.006

85. Lee, T. J., Cameron, L. D., Wünsche, B., & Stevens, C. (2011). A randomized trial of computer-based communications using imagery and text information to alter representations of heart disease risk and motivate protective behaviour. *British Journal of Health Psychology, 16*(1), 72-91. https://doi.org/10.1348/135910710X511709

86. McBride, C., De Heer, H., Tekola Ayele, F., & Davey, G. (2019). Using genomic knowledge to improve health promotion interventions in the developing world. In E. B. Fisher, L. D. Cameron, A. J. Christensen, E. Ulrike, Y. Gao, B. Oldenburg, & F. J. Snoek (Eds.), *Principles and Concepts of Behavioral Medicine: A Global Handbook* (pp. 713-736). New York, NY: Springer.

87. Lorenzoni, I., Nicholson-Cole, S., & Whitmarsh, L. (2007). Barriers perceived to engaging with climate change among UK public and their policy implications. *Global Environmental Change, 17*(3-4), 445-459. https://doi.org/10.1016/j.gloenvcha.2007.01.004

88. Hornsey, M. J., Chapman, C. M., & Oelrich, D. M. (2021). Why is it so hard to teach people they can make a difference: Climate change efficacy as a non-analytic form of reasoning. *Thinking and Reasoning,* https://doi.org/10.1080/13546783.2021.1893222

89. Gulliver, R., Chapman, C. M., Solly, K., & Schultz, T. (2020). Testing the impact of images in environmental campaigns. *Journal of Environmental Psychology, 71,* 101468. https://doi.org/10.1016/j.jenvp.2020.101468

90. Peters, E., Shoots-Reinhard, B., Shoben, A., Evans, A.T., Klein, E., Tompkins, M.K., Romer, D., & Tusler, M. (2019). Pictorial warning labels and memory for cigarette health-risk information over time. *Annals of Behavioral Medicine, 53*(4), 358–371. https://doi.org/10.1093/abm/kay050

91. Shoots-Reinhard, B., Erford, B., Romer, D., Evans, A. T., Shoben, A., Klein, E. G., & Peters, E. (2020). Numeracy and memory for risk probabilities and risk outcomes depicted on cigarette warning labels. *Health Psychology, 39*(8), 721-730. https://doi.org/10.1037/hea0000879

92. McCaul, K. D., Mullens, A. B., Romanek, K. M., Erickson, S. C., & Gatheridge, B. J. (2007). The motivational effects of thinking and worrying about the effects of smoking cigarettes. *Cognition and Emotion, 21*(8), 1780-1798. https://doi.org/10.1080/02699930701442840

93. Boomsma, C., Pahl, S., & Andrade, J. (2016). Imagining change: An integrative approach toward explaining the motivational role of mental imagery in pro-environmental behavior. *Frontiers in Psychology, 7,* 1780. https://doi.org/10.3389/fpsyg.2016.01780

94. Nicholson-Cole, S. A. (2005). Representing climate change futures: A critique on the use of images for visual communication. *Computer Environments and Urban Systems, 29*(3), 225-273. https://doi.org/10.1016/j.compenvurbsys.2004.05.002

95. Hansen, A., & Machin, D. (2013). Researching visual environmental communication. *Environmental Communication, 7*(2), 151-168. https://doi.org/10.1080/17524032.2013.785441

96. Bator, R. J., & Cialdini, R. B. (2000). The application of persuasion theory to the development of effective proenvironmental public service announcements. *Journal of Social Issues, 56*(3) 527-541. https://doi.org/10.1111/0022-4537.00182

97. Moser, S. C. (2010). Communicating climate change: History, challenges, process and future directions. *WIREs Climate Change, 1*(1), 31-53. https://doi.org/10.1002/wcc.11

98. Guber, D. L. (2013). A cooling climate for change? Party polarization and the politics of global warming. *American Behavioral Scientist, 57*(1), 93–115. https://doi.org/10.1177/0002764212463361

99. Jones, M. D. (2014), Cultural characters and climate change: How heroes shape our perception of climate science. *Social Science Quarterly, 95*(1), 1-39. https://doi.org/10.1111/ssqu.12043

100. Hinyard, L. J., & Kreuter, M. W. (2007). Using narrative communication as a tool for health behavior change: A conceptual, theoretical, and empirical overview. *Health Education & Behavior, 34*(5), 777–792. https://doi.org/10.1177/1090198106291963

101. de Graaf, A., Hoeken, H., Sanders, J., & Beentjes, J. W. J. (2012). Identification as a mechanism of narrative persuasion. *Communication Research, 39*(6), 802–823. https://doi.org/10.1177/0093650211408594

102. Fløttum, K., & Gjerstad, Ø. (2017). Narratives in climate change discourse. *WIREs Climate Change, 8*(1), e429. https://doi.org/10.1002/wcc.429

103. Brown, P. (2017). Narrative: An ontology, epistemology and methodology for pro environmental psychology research. *Energy Research and Social Science, 31*, 215–222. https://doi.org/10.1016/j.erss.2017.06.006

104. Jovchelovitch, S. (2012). Narrative, memory and social representations: A conversation between history and social psychology. *Integrative Psychological & Behavioral Science, 46*(4), 440–456. https://doi.org/10.1007/s12124-012-9217-8

105. McBeth M. K., Jones M. D., & Shanahan E. A. (2014). The narrative policy framework. In P. A. Sabatier & C. Weible (Eds.), *Theories of the Policy Process* (pp. 225–266). Boulder, CO: Westview Press.

106. Dal Cin, S., Zanna, M. P., & Fong, G. T. (2004). Narrative persuasion and overcoming resistance. In E. S. Knowles & J. A. Linn (Eds.), *Resistance and Persuasion* (pp. 175-180). UK: Psychology Press.

107. Green, M. C., & Brock, T. C. (2000). The role of transportation in the persuasiveness of public narratives. *Journal of Personality and Social Psychology, 79*(5), 701-721. https://doi.org/10.1037/0022-3514.79.5.701

108. Green, M. C., & Brock, T. C. (2002). In the mind's eye: Transportation-imagery model of narrative persuasion. In M. C. Green, J. J. Strange, & T. C. Brock (Eds.), *Narrative impact: Social and cognitive foundations* (pp. 315-341). Mahwah, NJ: Lawrence Erlbaum.

109. Houston, T. K., Allison, J. J., Sussman, M., Horn, W., Holt, C. L., Trobaugh, J., Salas, M., Pisu, M., Cuffee, Y. L., Larkin, D., Person, S. D., Barton, B., Kiefe, C. I., & Hullett, S. (2011). Culturally appropriate storytelling to improve blood pressure: A randomized trial. *Annals of Internal Medicine, 154*(2), 77–84. https://doi.org/10.7326/0003-4819-154-2-201101180-00004

110. Busselle, R., & Bilandzic, H. (2009) Measuring narrative engagement. *Media Psychology, 12*(4), 321-347. https://doi.org/10.1080/15213260903287259

111. Murphy, S. T., Frank, L. B., Chatterjee, J. S., & Baezconde-Garbanati, L. (2013). Narrative versus non-narrative: The role of identification, transportation, and emotion in reducing health disparities. Journal of Communication, 63(1), 116–137. https://doi.org/10.1111/jcom.12007

112. Böhm, G., Pfister, H. R., Salway, A., & Fløttum, K. (2019). Remembering and communicating climate change narratives - The influence of world views on selective recollection. *Frontiers in Psychology, 10*, 1026. https://doi.org/10.3389/fpsyg.2019.01026

113. Jones, M. D. & Song, G. (2014). Making sense of climate change. *Political Psychology, 35*(4), 447-476. https://doi.org/10.1111/pops.12057

114. Lowe, T., Brown, K., Dessai, S., de França Doria, M., Haynes, K., & Vincent, K. (2006). Does tomorrow ever come? Disaster narrative and public perceptions of climate change. *Public Understanding of Science, 15*(4), 435–457. https://doi.org/10.1177/0963662506063796

115. Shaffer, V. A., Focella, E. S., Hathaway, A., Scherer, L. D., & Zikmund-Fisher, B. J. (2018). On the usefulness of narratives: An interdisciplinary review and theoretical model. *Annals of Behavioral Medicine, 52*(5), 429–442. https://doi.org/10.1093/abm/kax008

116. Böhm, G., & Pfister, H. R. (2001). Mental representation of global environmental risks. In G. Böm, J. Nerb, T. McDaniels, & H. Spada (Eds.), *Environmental Risks: Perception, Evaluation and Management: Research in Social Problems and Public Policy*, Vol. 9 (pp. 1-30). Bingley, UK: Emerald Group Publishing Limited.

117. Pfister, H. R. & Böhm, G. (2001). Decision making in the context of environmental risks. In: C. M. Allwood & M. Selart (Eds.), *Decision Making: Social and Creative Dimensions* (pp. 89-111). Dordrecht, Netherlands: Springer.

118. Dahlstrom, M. F., & Scheufele, D. A. (2018). (Escaping) the paradox of scientific storytelling. *PLoS Biology, 16*(10), e2006720. https://doi.org/10.1371/journal.pbio.2006720

119. Tàbara, D. J., Jäger, J., Mangalagiu, D., & Grasso, M. (2018). Defining transformative climate science to address high-end climate change. *Regional Environmental Change, 19*, 807–818. https://doi.org/10.1007/s10113-018-1288-8

120. OECD. (2013). OECD skills outlook 2013: First results from the survey of adult skills. *OECD Publishing*. http://dx.doi.org/10.1787/9789264204256-en

121. Schwartz, P. H. (2011). Decision aids, prevention, and the ethics of disclosure. *Hastings Center Report*, *41*(2), 30– 39. https://doi.org/10.1353/hcr.2011.0029

122. Wallsten, T. S., Budescu, D. V., Zwick, R., & Kemp, S. M. (1993). Preferences and reasons for communicating probabilistic information in verbal or numerical terms. *Bulletin of the Psychonomic Society*, *31*(2), 135– 138. https://doi.org/10.3758/BF03334162

123. Lazard, A. J., Byron, M. J., Vu, H., Peters, E., Schmidt, A., & Brewer, N. T. (2019). Website designs for communicating about chemicals in cigarette smoke. *Health Communication, 34*(3), 333-342. https://doi.org/10.1080/10410236.2017.1407276

124. Fischhoff, B. (2019). Evaluating science communication. *Proceedings of the National Academy of Sciences, 116*(16), 7670-7675. https://doi.org/10.1073/pnas.1805863115

125. Peters, E., Hart, S., Tusler, M., & Fraenkel, L. (2014). Numbers matter to informed patient choices: The effects of age and numeracy. *Medical Decision Making, 34*(4), 430-442. https://doi.org/10.1177/0272989X13511705

126. Myers, T.A., Maibach, E., Peters, E., & Leiserowitz, A. (2015). Simple messages help set the record straight about scientific agreement on human-caused climate change: The results of two experiments. *PLoS ONE, 10*(3), e0120985-e0120985. https://doi.org/10.1371/journal.pone.0120985

127. Hart, P. S. (2013). The role of numeracy in moderating the influence of statistics in climate change messages. *Public Understanding of Science, 22*(7), 785–798. https://doi.org/10.1177/0963662513482268

128. Gigerenzer, G. (2011). What are natural frequencies? *The British Medical Journal, 343*, d6386. https://doi.org/10.1136/bmj.d6386

129. Thorpe, A., Scherer, A.M., Han, P.K.J., Burpo, N., Shaffer, V., Scherer, L., & Fagerlin, A. (2021). Exposure to common geographic COVID-19 prevalence maps and public knowledge, risk perceptions, and behavioral intentions. *JAMA Network Open*, 4(1), e2033538. doi:10.1001/jamanetworkopen.2020.33538

130. Peters, E. (2020). *Innumeracy in the wild: Misunderstanding and misusing numbers*. Oxford University Press. doi:10.1093/oso/9780190861094.001.0001

131. Zaval, L., Keenan, E., Johnson, E., & Weber, E. U. (2014). How warm days increase belief in global warming. *Nature Climate Change, 4*, 143–147. https://doi.org/10.1038/nclimate2093

132. Weber, E. U. (2020). Seeing is believing: Understanding & aiding human responses to global climate change. *Daedalus, 149*(4): 139–150. https://doi.org/10.1162/daed_a_01823

133. Sparkman, G., Attari, S. Z., & Weber, E. U. (2021). Moderating spillover: Focusing on personal sustainable behavior rarely hinders and can boost climate policy support. *Energy Research & Social Science, 78*, 102150. https://doi.org/10.1016/j.erss.2021.102150

134. Johnson, E. J., Shu, S. B., Dellaert, B. G. C., Fox, C., Goldstein, D. G., Häubl, G., Larrick, R. P., Payne, J. W., Peters, E., Schkade, D., Wansink, B., & Weber, E. U. (2012). Beyond nudges: Tools of a choice architecture. *Marketing Letters, 23*, 487–504. https://doi.org/10.1007/s11002-012-9186-1

135. Peters, E., Dieckmann, N., Dixon, A., Hibbard, J. H., & Mertz, C. K. (2007). Less is more in presenting quality information to consumers. *Medical Care Research and Review, 64*(2), 169–190. https://doi.org/10.1177/1077558707070640020301