AN EVALUATION OF METAPHORS IN CLIMATE CHANGE DISCOURSE

by

Jenell M. Walsh-Thomas
A Dissertation
Submitted to the
Graduate Faculty
of
George Mason University
in Partial Fulfillment of
The Requirements for the Degree
of
Doctor of Philosophy
Environmental Science and Public Policy

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Date: __Thursday, November 17, 2016__ Fall Semester 2016
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DEDICATION

This is dedicated to my unconditionally loving and supportive parents, Teresa Walsh and Mark Thomas.

ACKNOWLEDGEMENTS

The saying "it takes a village" certainly applies to writing a dissertation. Ultimately this is my accomplishment, but I have truly appreciated the support of 'my village' throughout my PhD journey.

I would very much like to express my gratitude to Dr. Ed Maibach, my advisor, for first taking me on as his student although I was outside of his department, as well as for his guidance through communication theory and research. I also wish to thank my other committee members, Dr. Chris Parsons, Dr. Kathy Rowan, and Dr. Erin Peters-Burton. Chris, thank you for being my department representative on my committee and for your continuous guidance throughout the dissertation process. I also thank you for your support and guidance through developing and implementing the environmental communication course for undergraduates. Kathy, I have sincerely valued the time you have taken to discuss my initial thoughts on my dissertation, and your thoughtful and constructive feedback on my writing. Erin, I cannot thank you enough for the time you have taken to be on my committee and meeting with me to talk through my research design and statistical analyses. Your methodological expertise has been truly invaluable and I have learned so much in the process.

I would like to very much thank my parents, Teresa and Mark, for their love and encouragement in everything I do. You have both been so patient and were never the parents asking "are you done yet?" I'm very thankful that my Father has shared his awe of science with me as far back as I can remember. I think his enthusiasm for science has played a big role in my desire to encourage others' understanding of and to become more excited about science. And Dad, you have always told me I was smarter than you, but now I have proof! (We have joked about this after my masters I was *as smart* as you; now I am smarter than you! Haha!) I thank my Mother for her willingness to always be there to listen and for being my occasional needed distraction. While I might have written as a preschooler that I "run errands with Mom, and have fun with Dad," I think us girls have a lot of fun and the best mother-daughter relationship (and it's not just because I wrote about all the fun things Mom did with me / took me to in all those journals you insisted I write). I love you both, and can't wait for fun family time at the beach without schoolwork!

My heartfelt thanks also goes to Advait. While we might be studying very different things, I have always appreciated being able to talk through what we are each struggling with, celebrating PhD milestones along the way, and having a partner who understands the dissertating process. You have been there through a lot of long days and nights of data analysis and writing; and with a lot of that hard work, we have found time to have some fun and enjoy time together. You're next!!

I also owe thanks to, and give a shout out to many of my other friends, colleagues, and mentors who have supported me or who have provided a much needed distraction here and there: to my 4C colleagues and friends – Chris, Karen, Jenny, Ashley, Brittany, Joe, Bia, Justin, Jagadish, John, and Moe – you all have challenged me, and provided feedback, encouragement, insightful discussions in and out of the office, and friendship. For all of that I am grateful.

My experience with the National Park Service through a partnership with 4C has had a significant influence on my career trajectory. First and foremost, I would like to thank Giselle Mora-Bourgeois for being the best mentor I could have asked for. Your dedication, passion, and professionalism have set such an incredible model and I hope something that I can emulate. I have truly appreciated your support and encouragement. Melissa Clark – we became such good friends through our work together as interns with 4C and NPS, and even better friends outside of our work. I could not have asked for a better partner dynamic for our projects. I think you have spoiled me, and can only hope I will find equally enthusiastic, hard-working, dedicated, astute, and compatible colleagues wherever I end up. I hope one day our work will cross paths again. I would like to also thank all of the NPS staff that I have interacted over the years. Everyone I had the opportunity to work with was nothing short of incredible. Their dedication and enthusiasm for what they do is contagious and inspiring. Here's to the next 100 years!

Lastly, I would like to thank: Sharon Bloomquist in the Environmental Science and Policy Department for her help navigating department and university paperwork and policies while completing my degree; Julie Choe Kim in the Grad Life office for all the graduate student programs she has grown and improved over the years; Dr. Cody Edwards for the GRA opportunity in the Provost's Office which provided an administrative perspective on higher education; the Qualtrics team for making my survey data collection go smoothly and fit my budget; and Allison, Katie, Alli, Fiorella, and Chris Lee for being awesome and encouraging friends.

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ABSTRACT

AN EVALUATION OF METAPHORS IN CLIMATE CHANGE DISCOURSE

Jenell M. Walsh-Thomas, Ph.D.

George Mason University, 2016

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Anthropogenic climate change is currently one of the biggest threats facing the human population across the globe. Most Americans, however have little understanding of this threat, and as a result may be ill-prepared to make important personal and societal decisions necessary to deal with it. This dissertation explores the practicality, usefulness, and effectiveness of metaphors as a means of enhancing public understanding of climate change. Three sequential studies were conducted to develop, test, and refine a set of science, metaphorical, and 'science + metaphorical' explanations of four basic climate change concepts: the frequency of extreme weather events; the increasing rate of carbon dioxide in the atmosphere; the enhanced greenhouse effect; and the difference between weather and climate. In the first study, in-depth interviews were conducted with experts (n = 12) to explore the adequacy of the 'science + metaphorical' explanations of the climate concepts, each expressed in approximately 520 to 650 word essay. Overall, the experts were intrigued by the metaphors and viewed them as a promising way to explain and connect to lay audiences. The expert feedback was used to revise each of the explanatory essays. In the second study, in-depth interviews were conducted with non-scientists (n = 30) to explore how helpful and clear the essays were to a lay audience. The non-expert participants identified the metaphors as helpful to their understanding of the topic climate change concept. While the non-experts appeared more confident in explaining climate change after reading the short essays, the metaphors were infrequently rearticulated in their improved and more detailed explanations. The essays were edited again to clarify points of confusion identified in these interviews. The third study was an experiment which members of the public (n = 1523) were randomly assigned to read about one climate change concept explained using one of three explanation types (science only, metaphor only, or 'science + metaphor'). There was some evidence that the 'science + metaphor' explanations worked as hypothesized in improving participants' understanding and increasing belief certainty that climate change is happening. However, the differences observed between explanation types for the four climate change concepts were mostly non-significant. In total, the results of this dissertation suggest that metaphors may be useful in explaining climate change concepts to lay audiences. Additional theoretical and practical implications for the three studies are also discussed.

CHAPTER 1. INTRODUCTION

Climate change is complicated. The complexities of climate change are scientific, social, and political, making it is an intrinsically difficult to understand. A majority of Americans do not have a strong or clear understanding of climate change concepts; and based on a series of knowledge questions, 52% receive a “failing grade” (Leiserowitz, Smith, & Marlon, 2010). The lack of understanding or misconceptions about climate change hinders Americans’ ability to make productive decisions and perhaps take proactive action to address the effects of human-induced climate change. Climate change is also a challenge for Americans because of geographic and temporal scales at which the impacts of climate change are being observed and experienced (Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Rosenthal, 2015; Moser, 2010; National Research Council, 2009). Scientists assuming that understanding a topic leads automatically to agreement has created a knowledge and information usability gap (Lemos, Kirchhoff, & Ramprasad, 2012). Climate scientists also are perceived as experts, though this is not sufficient in order to be believed and trusted, and thus influences the acceptance of information (Fiske & Dupree, 2014; Lupia, 2013). Metaphors draw connections between what is familiar and unfamiliar and facilitate a greater understanding of a concept. Processing information in such a way allows for a complex cognitive task to be surmountable by making associations with experiences.

Climate science has produced a substantial amount of useful information; however, many experts have observed that this information is not being used by decision-makers outside the climate science domain to nearly the degree that it could, and likely should. For example, information on negative impacts – both current and projected – can be of considerable value in making better decisions about mitigation and adaptation. It is imperative to identify and/or develop mechanisms through which such information can be effectively communicated to increase its usefulness to decision-makers and members of society at large. Any such approach should allow for an easier transition into a usable format to better inform a wide range of necessary and important decisions being made by local and national governments, businesses, organizations, and ordinary, private citizens. However, there are substantial challenges evident in both real-world events and as expressed in literature to reaching such a goal.

My dissertation explores the use of metaphors for making useful and basic climate science information more usable, understandable, and relatable. The main motivation is to understand how metaphors work (or do not work) and influence the narrowing of the climate science and knowledge usability gap. Additional motivation stems from the fact that the public largely views climate scientists as trusted and credible sources on climate change (Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Howe, 2012; Leiserowitz, Maibach, Roser-Renouf, Smith, & Hmielowski, 2011).

1.1 The Climate Change Information Usability Gap

The climate information usability gap describes the situation that occurs when useful climate science information is not used by decision-makers outside the scientific domain as a consequence of the failure to transform useful and pertinent information into usable information. In common language, *useful* is defined as being "valuable or productive" while *usable* is defined as "capable of being used or convenient and practicable for use" (Merriam-Webster Dictionary). In essence, useful refers to the functionality and desirability while usable suggests application (Lemos & Rood, 2010). In a public policy context, Congress established the U.S. Global Change Research Program (USGCRP) in 1990 defining and acknowledging the importance of usable information in the context of climate change. Left open to interpretation, the statute superficially states science should advance the understanding of global change and notes that usable information is knowledge produced by scientists which should be "readily usable by policymakers attempting to formulate effective strategies for preventing, mitigating and adapting to the effects of global change" . The ambiguity of this language allows for interpretation of usable to be synonymous with useful. However, the terms are distinguishable rather than interchangeable (McNie, 2007), and should not be misconstrued.

Climate science and decision-making are clearly separate and distinguishable processes, but are also dependent on each other and it is necessary for both to work as a cohesive faction and efficiently communicate to narrow the climate information usability gap. Subject-matter experts, decision scientists, social and communication scientists, and program designers can or should work together for more effective communication of climate science (Pidgeon & Fischhoff, 2011). Scientists and decision-makers – including policy makers in government and business, as well as members of the public – though often perceive usefulness and usability of climate information differently. This difference in perception between what is useful versus usable, Lemos et al. (2012) argue, is due to how each perceive scientific information generally. Both cultures have different concerns, purposes, languages, norms and temporal needs (Blockstein, 2002; Dabelko, 2005; Guston, 2001; S. Jasanoff, 1986; Nagda, 2006; National Research Council, 2009). These differences create a challenging environment for collaborative efforts needed to make informed and effective climate related decisions for the benefit of society.

Usable science production for decision support has been demonstrated through several mechanisms, bringing science and decision-making together, for example: information brokers (Cash, Borck, & Patt, 2006; McNie, 2007), collaborative processes (Power, Sadler, & Nicholls, 2005; Pulwarty & Melis, 2001), knowledge systems (Cash et al., 2003), embedded capacity (Pagano, Hartmann, & Sorooshian, 2001), boundary organizations (Cash et al., 2006; Lemos & Morehouse, 2005; McNie, 2007), and knowledge networks (Feldman & Ingram, 2009). Such mechanisms involve scientists and decision makers which produce usable science by incorporating three functions: *communication* that is active, iterative and inclusive; *translation* of science enhancing understanding; and active *mediation* of conflicts that arise (Cash et al., 2003). Engaging both scientists and decision makers in these systems to produce usable knowledge increases understanding, respect, and trust for all involved (Hahn, Olsson, Folke, & Johansson, 2006; S. Jasanoff, 1986; McNie, 2007). Other important factors leading to the production of usable science include ensuring activities have a level of fit between knowledge produced, needed and used; flexibility of producers and users in the process;

and maintenance of financial and human resources (Lemos & Morehouse, 2005). These functions combined have shown to result in better decisions and outcomes, in addition to constituents of decision makers also perceiving the decisions as positive and encouraging (Clark, Mitchell, & Cash, 2006; National Research Council, 2009).

On an issue such as climate change where there is a broad range of impacts, conceptual information needs to be usable and applicable at many levels. Applying these approaches directly to a larger scale and audience are likely to prove challenging and unsuccessful. Thus ideas from these successful approaches can be leveraged to employ other communication techniques, which have a potential to be more persuasive to be actually used, and have a broader appeal and reach to close the usability gap. Metaphors can be used as a tool – to communicate, translate, and mediate – in addition to these current approaches with the potential to employ the small-scale approaches more frequently and/or at a larger scale to reach a broader audience of decision makers. From this we can begin to derive the following proposed incorporation of metaphors to transition useful information into usable information and tapping into available cognitive research that has examined the way users process information communicated to them.

1.2 Incorporating Metaphor into Climate Change Discourse

This dissertation examines the usage of metaphor in the communication of climate change, and the subsequent effects on the public's understanding of climate science and perceptions of climate change. The central interest herein is how metaphors are used in climate change outreach and communication by scientists to a variety of audiences and the evaluation of possible outcomes. Using such a technique in explanatory discourse – a type of discourse designed to deepen understanding of complexities – can assist non-expert audiences in visualizing the main components of phenomena that involve many processes (Rowan, 1988, 2003, in press). Metaphors are logical communication tools that have been shown to improve communication effectiveness in several disciplines. For example, science education literature has provided several good examples demonstrating how metaphors offer many benefits and have the potential to: 1) improve understanding and comprehension; 2) enhance the ability to remember commonly difficult concepts; 3) correct misconceptions; and 4) motivate individuals to believe that they can indeed learn and understand (Guerra-Ramos, 2011).

Using metaphor as a communication technique is an intuitive way to share useful information because metaphors are explanatory devices that facilitate the understanding of complex concepts. Climate scientists and climate change communicators already use a variety of metaphors. Common metaphors include the greenhouse effect to explain how the earth maintains an environment that supports life; and making a comparison between a bathtub overflowing with water and the atmosphere "overflowing" with greenhouse gases. Another metaphor that is used describes a tipping point where something falls over the edge with nothing able to stop it; in the case of climate change, the something is the increasing rate of greenhouse gases elevating the global average temperature to a point where human action cannot stop or slow the temperature increase. However, whether these metaphors resonate well with non-experts and have meaningful impacts on their knowledge, belief, concern and motivation to action is uncertain.

1.3 The Importance and Potential of Metaphor in Climate Change Discourse

Metaphors can be developed which are credible, salient, reliable, legitimate, and widely understood by leveraging accepted climate science from experts in the field and understanding non-expert mental models. Such a communication technique may result in messages designed to have various effects for a wide range of audiences whether it be as simple as increasing issue engagement, caring, or concern, to problem recognition that leads to an action that an individual, community or nation takes. The construction of usable climate change metaphors works towards the framing of climate science in a meaningful, personal and emotional way, all while not losing scientific credibility. This helps move towards the suggested goal put forth by Ockwell, Whitmarsh, and O'Neill (2009) to achieve meaningful engagement through understanding, emotion, and behavior.

The notion that climate scientists have great knowledge – and therefore a great responsibility to communicate such knowledge effectively, simply, and concretely – is not a new concept (Hassol, 2008). As identified by Hulme (2012) there are several noteworthy scientists particularly calling for current climate science knowledge to be put to use. While there is still a strong belief that scientific endeavors should be continued to improve our understanding of climatic systems, it is questionable if new knowledge will demonstrably lead to motivating action more than the current state of understanding (Rowan, in press). The science is already clear that climate change is real, significantly influenced by human activities, it is harmful to people and other planetary life and systems. Moreover, solutions have and are being developed, and an overwhelming majority of scientists agree that it is both caused by humans and is a major threat (Cook et al., 2016). The fact that an increasing number of scientists see this set of existing knowledge as sufficient evidence to motivate action supports the need for scientists to publicly advocate for such action and to communicate without fear about what we know and what we need to do (Anderson & Bows, 2012; Hansen, 2007). Demonstrating the usefulness of communication tools like metaphor should increasingly play a larger role in motivating scientists to speak up and work on closing the usability gap so that decision makers follow through with necessary action.

1.4 Pilot Study

In October 2014, a pilot message testing experiment was conducted with 1011 Amazon Mechanical Turk (MTurk) participants. The primary purpose of the study was to determine if metaphors increase the understanding of climate science concepts, and perhaps influence beliefs about climate change. Additionally, it aimed to determine if more highly complex climate science concepts benefit more from the usage of metaphor than lower complexity climate science. There were a total of four scientific explanation passages, four metaphor explanation passages, and four science and metaphor combination passages, for a 12 total treatments. The four climate science concepts that were explained and tested: (1) frequency of extreme weather events; (2) rate of CO_2 entering the atmosphere; (3) the (enhanced) greenhouse effect; and (4) the difference between weather and climate. The metaphors, respectively were: (1) the frequency of homeruns hit by a baseball player on steroids; (2) the rate at which water enters and exits a bathtub; (3) the effect on the interior temperature of a parked car in the summer sun, and (4) baseball statistics – the outcome of a baseball player up at bat and his batting average. The study also included one unrelated, control essay (topic: the new Star Wars film), which was the 13^{th} treatment.

Participants were asked to score their familiarity with the concept (1, not at all familiar and 5, extremely familiar) and were asked a few knowledge questions (forced-response, true/false items) to then gauge their "actual familiarity" for the base and target concepts of selected topics. The pre-test also included questions regarding: belief certainty that climate change is happening; belief climate change is human caused; scientific consensus; trust in scientists; harm; issue importance; and policy support. Following that, study participants were randomly assigned to read one of the 13 essays. The post-test consisted of an analogy multiple choice question (if a metaphor or combination condition was presented), knowledge questions (specific to the climate concept they read about), and again: belief certainty that climate change is happening, belief climate change is human caused, scientific consensus, trust in scientists, harm, issue importance, and policy support. Demographic questions were also included at the conclusion of the survey.

For the outcome variables (belief certainty, belief that climate change is human caused, trust in scientists) ANOVAs were conducted. While it was expected that the science + metaphor message would have the greatest effect in comparison to only the science and only the metaphor, the results demonstrated that there was no significant difference between the different explanatory passages. It was expected that the trend of the combination conditions, followed by the metaphor conditions would have the most and significant influence on the outcome variables measured. However, the results of the pilot experiment demonstrated that there was no distinct pattern within climate change concept or across outcome variable; and provide opportunity for improvements to be made in subsequent studies pertaining specifically to both message conditions and outcome measures.

Additionally, comparative analyses comparing across climate change concepts was problematic as the measurement of knowledge and comprehension were inconsistent. For each topic, rather than answering the same set of knowledge questions, there were specific questions unique to each topic (i.e. a participant who read about the greenhouse effect only received questions about the greenhouse effect), and hence was not truly comparable across conditions. With the counter-hypothetical findings of the pilot study, three follow-up studies were proposed and completed, which include methodological improvements as well as a more thorough and formal evaluation of selected metaphors. The first of the three studies involved interviewing experts to explore the scientific accuracy of the climate change narratives to be used in subsequent research stages. In the second study, a set of interviews were conducted to explore lay audience perceptions of the clarity of information presented as well as the degree to which climate change science was understood in conjunction with an explanatory metaphor. The third study was then able to leverage an improved set of essays derived from the previous two studies as well as enhancements to experimental methods (i.e. an open-ended question for each topic was used to measure understanding).

1.5 Dissertation Structure

Chapter 2 of this dissertation discusses the implicit and explicit aspects of metaphor as a construct. The chapter provides a rigorous examination of metaphor, how a metaphor works, and explains how, what, and where the effects of using metaphors in communication are observed. Chapters 3 through 5 include the three core studies, which employed a multiphase mixed methods research design (Figure 1). The research design combines multiple techniques that can help improve the validity of findings, and provide more in-depth data and analysis. In following such a procedure the results of the qualitative studies will inform the quantitative approach for a more comprehensive analysis of the effectiveness of metaphors in communicating climate change concepts. Chapters 3 and 4 (studies 1 and 2) involve in-depth interviews with experts and non-experts, respectively. These interviews aimed to provide expert validation of the metaphors used in a pilot study, and to gain a clearer picture of the mental models that other individuals construct towards understanding climate change and related concepts. Chapter 5 (study 3) leveraged the acquired expert validation and insight as well as the results of the non-experts interviews in improving and subsequently testing short climate change essays, which incorporate explanatory metaphors. These three sequential studies have provided an opportunity to improve on the shortcomings of the pilot study. The concluding chapter, Chapter 6, provides a summary discussion of the three sequential studies' findings, and the implications of each as well as collectively.

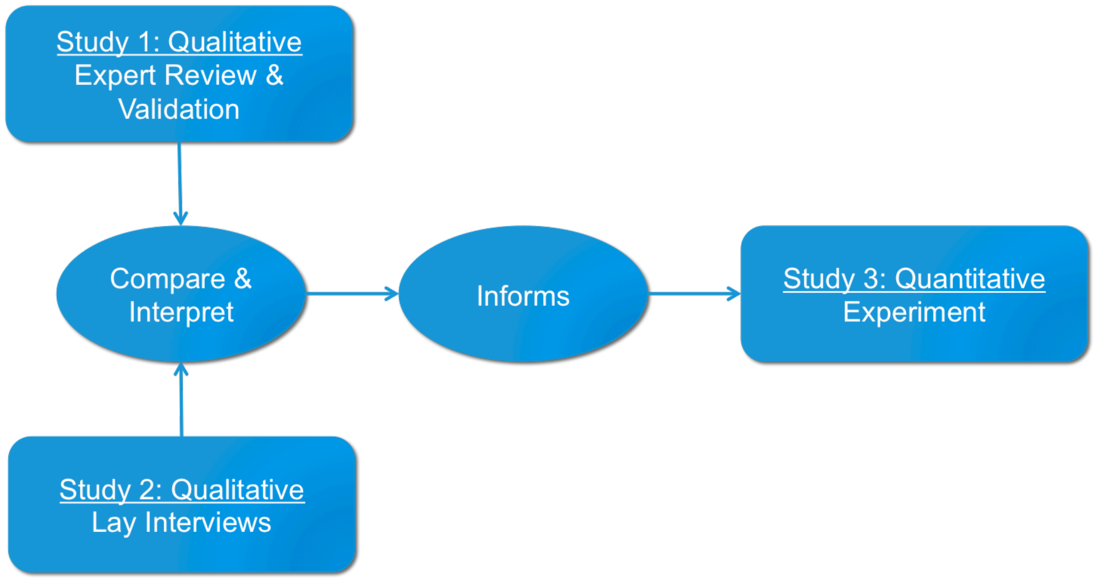

Figure 1. Multiphase mixed methods research design.
This dissertation took a multiphase mixed methods research design approach starting with two qualitative studies – interviewing experts and non-experts of climate change before and after reading explanatory essays using metaphors – which were used to inform a subsequent quantitative, message testing survey experiment.

CHAPTER 2. LITERATURE REVIEW – EXPLICATING METAPHOR

This chapter will provide an overview of metaphor as a construct through a literature review, which is necessary for metaphor to be understood. The term metaphor will be defined in this chapter, and will include an explanation of how metaphors work as well as how metaphors are studied. In explicating the metaphor construct, concepts that are similar and related to the notion of metaphor will be examined. Examples will be provided throughout to demonstrate how individuals might encounter metaphor usage and how researchers study these linguistic elements. Some examples will be specific to climate change, though others will be more general. An operational analysis will address qualitative and quantitative methods through which metaphors have been evaluated. Furthermore, mediating factors and outcomes of the use of metaphors in communicating will be reviewed. To conclude this chapter, research questions and hypotheses about metaphors used in climate change communication will be presented and justified.

2.1 Conceptual Analysis of Metaphor

Metaphors are figures of speech used to communicate about unfamiliar or less understood concepts by drawing comparisons between something that is familiar and unfamiliar. In a metaphor, a term is applied to something, which it is not literally applicable or related to; a metaphor merely suggests a resemblance between two unrelated concepts (Mayer, 1993). Metaphor can present very complex topics in more familiar and relatable terms while maintaining credibility, saliency, and legitimacy (Zaltman, 2003).

Metaphors are unintentionally and intentionally used to think and communicate about a variety of concepts. Some scholars, from a linguistic perspective, argue that human thought is inherently metaphoric (Lakoff & Johnson, 2003). For example, we use phrases such as the "sun rises," or refer to being on the phone as being "on the line." However, we know that the Earth revolves around the sun, and many of us use cellular phones that are not connected by a physical line. Lakoff and Johnson (2003) argue that since thought processes are largely metaphorical, our natural tendency is to communicate with metaphor. Due to such natural tendencies to communicate and express our ideas unknowingly using metaphor, it is appropriate and important to consider intentionally using metaphor to communicate certain ideas and concepts.

However, it is important to acknowledge the significant difference between certain types of metaphor: the *intentional* use to improve the understanding of a concept versus *unintentional* use with human language is inherently metaphorical. Metaphors can be hidden by using language that hides an aspect of our experience, a phenomenon called the "conduit metaphor" by Reddy (1979). Conduit metaphors lack context and are problematic across cultures that do not share the same knowledge, values, and assumptions thus mutual understanding is challenging (Lakoff & Johnson, 2003), as observed between the cultures of scientists and non-scientists (or scientists and policymakers). An example used by Lakoff and Johnson (2003, p. 12) is "We need new alternative sources of energy" which likely has different meanings to the president of

Mobil Oil compared with the president of Friends of the Earth; the possible new sources being a new oil drilling location and solar panels, respectively. In some cases, conduit metaphors are labeled as "dead metaphors" because they are both old and irrelevant, or have been used for such a long time they do not register during information processing as metaphor (Lakoff & Johnson, 2003). Some examples include: the arms of a chair, the legs of the table, and the foot of a mountain.

Other discourse that uses conduit metaphors also typically has a specialized audience. Such metaphors can be found in scientific discourse (i.e. peer-reviewed articles, or a domain specific magazine) when providing proof for a claim and can lead to a non-expert audience having a different or contradictory interpretation compared to an expert's interpretation. The phrase or term "global temperature" is part of scientific lexicon though it can be easily misunderstood by non-scientists (Brown, 2003). This is misleading because one cannot take the Earth's temperature literally; global temperature is an *average* of temperatures of individual locations across the globe. Hence conduit metaphors can be problematic and should not be used for explaining or conveying a message to a non-expert audience.

Therefore, the type of metaphor that is of interest here is *conventional* metaphor (also conceptual or structural) where the structure of one concept is non-literally translated to another concept in order to explain a concept or topic that is unfamiliar. For example, the metaphor "the ocean is like the climate's heart" conveys that the ocean is central to the climate system's vitality similar to the role of the human heart, which is vital to keeping a person alive and functioning. Conceptual metaphor can include how concepts are spatially related (orientational) and how something abstract can be represented by something more concrete (ontological) (Lakoff & Johnson, 2003). Examples of orientational metaphors include statements using polar oppositions like up-down, or in-out (Lakoff & Johnson, 2003). The phrase “he is at the peak of health” describes health as being “up” conveying health as positive and in a good state. Ontological metaphors, on the other hand gives the impression that a concept is a physical thing and describes something a physical object can do (i.e. inflation is an entity: inflation is *lowering* our standard of living) (Lakoff & Johnson, 2003). For simplicity, conceptual metaphor will be referred to as metaphor, and any other types will otherwise be explicitly identified.

Metaphor can be more formally defined as “an implied comparison between two dissimilar objects, such that the comparison results in aspects that normally apply to one object being transferred or carried over to the second object” (Sopory & Dillard, 2002, p. 382). Simply put, A is said to be B; where A and B are two different concepts being compared. The target (A) is the unfamiliar concept while the analogue or base (B) is the familiar concept (Gentner, 1983). As depicted in Figure 2, fundamental features and meanings of the analogue are compared or mapped onto the target and is highlighted using the baseball player on steroids metaphor, which helps explain climate change and the frequency of extreme weather events. This visualizes how a central topic of an analogy can be mapped (analogical mapping) by drawing similarities of features of the analogue and target that are being compared. This figure is an elaboration of a figure found in Guerra-Ramos (2011) and illustrates the abstract representation of an analogy as described by Glynn (1991).

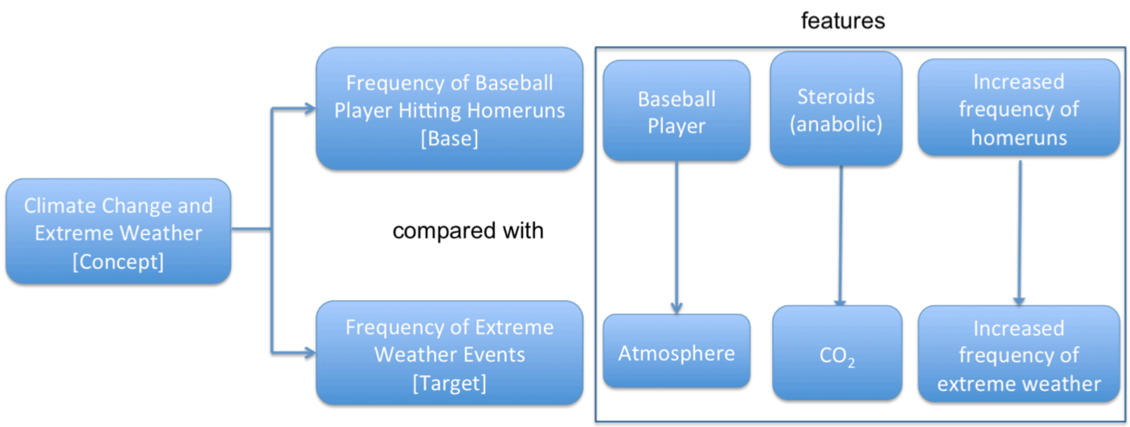

Figure 2. Diagram of a conceptual metaphor with examples of features of target and base concepts of the metaphor.
This figure uses the baseball player on steroids metaphor to explain the frequency of extreme weather events, and provides three examples of base-to-target feature mapping.

How metaphors work

Since metaphor is the representation of one thought in terms of another, cognitive learning processes are initiated and in turn inform decisions and subsequent action. In using metaphor, two forms of information processing are engaged. According to Kahneman (2011), to process unfamiliar information we engage in more analytic, system 2 thinking, whereas when we are presented with familiar information, we are more apt to engage in experiential, system 1 thinking. Experiential processing initiates a more intuitive, quick way of thinking, making connections for more immediate actions and decisions, and facilitates the encoding of reality in concrete images, metaphors and narratives (Epstein & Pacini, 1999; Epstein, Pacini, Denes-Raj, & Heier, 1996; Kahneman, 2011). Analytic processing however is based on past relevant experiences but is a slower, intentional, and more effortful process which is necessary for mental activities such as complex computations, deciphering abstract symbols, numbers, and words (Epstein & Pacini, 1999; Kahneman, 2011); more akin to the scientific process. It may be the case that metaphors work by linking these two systems, and enables us to use both to make connections between new information and already available information (Holyoak, Gentner, & Kokinov, 2001).

Complexity of concepts is also related to information processing, and plays a role in the comparisons made between a base and target of a metaphor. Complexity is the state or quality of being intricate or complicated and is often used when discussing technical concepts that can be difficult to understand. Edmonds (1995) has suggested that complexity is a property of language expression that even when complete information is provided about a concept, understanding the concept is difficult. Low complexity concepts are characterized by unidimensional, simple ideas. Such statements or concepts require more experiential information processing, such as a visual, schema, or mental model that quickly comes to mind. High complexity statements or concepts however are characterized by multidimensional ideas with many inter-relationships expressed. The higher complexity requires more analytical information processing, such as mathematical or statistical understanding (Schön, 1993). Presenting two unrelated concepts in parallel provides a frame for which an explanation is formed. Using an explanatory metaphor employs a low complexity concept to explain a high complexity one.

Familiarity is another component to how a metaphor works and how presented information is processed. Familiarity is the amount of accumulated experience with a specific concept and varies from person to person. Researchers also have measured familiarity as the state of having knowledge of or ease of understanding something (Bettman & Park, 1980; Feiereisen, Wong, & Broderick, 2008). Familiarity with the base can influence effectiveness of a metaphor. Since the base of the metaphor is the concept that contextualizes the target you are trying to communicate about, familiarity is key. If there is a lack of familiarity for the base, the comprehension of the target diminishes (Guerra-Ramos, 2011), the metaphor's effectiveness is reduced (Hoeffler & Herzenstein, 2011), and can lead to misinformation (Gentner & Markman, 1997). Similar trends have also been shown for target familiarity: higher levels of target familiarity have been shown to have greater persuasive power and therefore metaphor effectiveness (Sopory & Dillard, 2002).

Familiarity of a metaphor as a whole also influences the processing of a metaphor's content. The more familiar the metaphor and its components are, the better the comprehension (Blasko & Connine, 1993). The science education literature has highlighted how metaphors are important explanatory tools (Guerra-Ramos, 2011). Metaphors based on unfamiliar concepts are less likely to be re-called and hence the second step is the first place for such use to break down (Guerra-Ramos, 2011). Glynn and Takahashi (1998) conducted two experiments to examine understanding and recall of a metaphor that compares how a cell's functions relate to a factory, for example. The students receiving the metaphor condition performed significantly better immediately after and two weeks later than the control condition: understandability ratings were significantly higher, they recalled the metaphor comparing the cell to the factory, and made more correct connections between the base and target (Glynn & Takahashi, 1998).

Explanatory discourse and metaphor

One line of thought casts metaphors as a tool for accomplishing a specific communication goal: deepening understanding of a complex structure or process. According to (Rowan, 1991, 2003, in press), this communication goal is accomplished by explanatory discourse. Explanatory discourse can be found in several places that individuals may encounter: textbooks, encyclopedia entries, feature stories in magazines, dictionaries, various internet sites whose purpose is to increase understanding, among others. An example might be found in a science textbook chapter where headings and subheadings are used to outline and organize the key concepts and topics students are learning about. The headings and subheadings help make connections from one section to the next. Perhaps in the case of metaphor, of the three types of explanatory discourse the most important type is quasi-scientific explanation. For example, one might compare what you choose to wear each day with the daily weather and your whole wardrobe to the climate. Such a comparison is aimed to help the audience to identify that weather and climate are related but different, and daily weather events are averaged to characterize and determine the larger concept of climate.

As evident in defining metaphor above, researchers (e.g. Kendall-Taylor, et al, 2013; Volmert, 2014) often call the metaphors used in messages “explanatory metaphors” because they function as explanatory devices. Metaphor is common in quasi-scientific explanation because it is especially effective at helping audiences envision structures and processes. To explain the importance of wetlands, a human health related metaphor is used: a wetland is nature's kidneys – in the sense that a wetland filters environmental pollutants just as kidneys filter bodily impurities.. This provides an experiential sense of the critical role wetlands play in an environment (Ausubel, 1960; Shapiro, 1986; Simons, 1984). The key value of explanatory metaphor is that there is the possibility to fill in gaps between the discourse of experts and non-experts (McGlone, 2007; Volmert, 2014) and serve to deepen the understanding about a [complex] topic. As effective learning aids, metaphors make abstract topics more concrete, as they leverage vivid descriptors and known concepts to explain a more abstract concept (Davidson, 1976).

Academic fields where metaphor is studied

An increasing body of literature has drawn attention to the use and importance of metaphor as an effective communication tool. Metaphors have been studied across several academic fields, including [science] education (Guerra-Ramos, 2011; Halpern, Hansen, & Riefer, 1990); politics (Mio, 1997); new product consumerism and advertising (Ait El Houssi, Morel, & Hultink, 2004); health communication (Galesic & Garcia-Retamero, 2013; Gülich, 2003); biodiversity education (Väliverronen & Hellsten, 2002); and environmental and climate change science communication (van der Linden, Leiserowitz, Feinberg, & Maibach, 2014). The effects of metaphor have been evaluated qualitatively through interviews, as well as quantitatively in survey-based experiments (Kendall-Taylor, Erard, & Haydon, 2013). These studies demonstrate that the set up or presentation of a metaphor can allow for novices to have increased comprehension, thus filling a gap between expert and non-expert knowledge (Gülich, 2003; Morgan, Fischhoff, Bostrom, & Atman, 2002).

When used as a literary device, metaphor can be used to persuade (Bosman, 1987; Bosman & Hagendoorn, 1991; Sopory & Dillard, 2002); conjure emotions (Harrington, 2012; Lakoff & Johnson, 2003); and visualize phenomena (Hamill, Wilson, & Nisbett, 1980; Zaltman, 2003). Metaphor also plays an important role in building communicator-audience relationships. The use of metaphor can influence evaluations of communicator credibility (McCroskey & Combs, 1969) and help create a connection between a speaker and a listener (or reader) (Gibbs, 1987). More commonly metaphors serve to provide structure to knowledge, as well as transform and create new knowledge (Kazmerski, Blasko, & Dessalegn, 2003; Turner & Lakoff, 1989; Volmert, 2014). With the connections that metaphors make, they provide insight and enhance the meaning of complex concepts (Lakoff & Johnson, 2003; Mio, 1997). Metaphors have also been shown to increase memorability of concepts (Whitney, Budd, & Mio, 1996) and illuminate, clarify, explain, reduce ambiguity, and increase understanding (Kendall-Taylor et al., 2013; Ortony, 1975; Volmert, 2014).

Similar and related terminology

In the literature reviewed, several concepts appear that are similar to, or are variations of metaphor, are defined and explored. It is important to distinguish between the different types of metaphor, as well as other similar and related terminology. This section will discuss concepts that social scientists study (analogies, advance organizers, and bridging), as well as concepts that are notions created by researchers as tools for learning and sense making of complex concepts (concept maps, mental models).

Analogy

The most common term that is used synonymously with metaphor is *analogy*. Within and between domains previously mentioned, the terms are also used interchangeably, complicating the distinction (Aubusson, Harrison, & Ritchie, 2006). One distinction between the two is a matter of phrasing: a metaphor is phrased as A *is said to be* B, and an analogy is phrased as A *is like* B (see Figure 1 for conception of A and B). Gentner and Bowdle (2001) use the example of “the mind is a computer” and “the mind is like a computer” to demonstrate this difference and the influence of phrasing. The first statement categorizes the target in the base concept category whereas the second statement is a literal comparative statement. Comparisons made in a metaphor though are often covert while in analogy comparisons are more overt (Lakoff & Johnson, 2003). For example, analogy identifies explicitly both differences and similarities between concepts, whereas metaphor identifies attributes of concepts that are similar but not explicitly made. Defining analogy as identifying similarities and differences of a concept equates analogy with Lakoff and Johnson’s definition of *structural* metaphor, a more specific type of metaphor. Since metaphors make comparisons between concepts, and analogy is an extension of making such comparisons by also including differences between concepts, all analogies are metaphors (Aubusson et al., 2006). They also often have the same goals and achieve similar outcomes (i.e. to improve knowledge, correct misinterpretations, provide an explanation). Additionally, metaphor and analogy instigate the same cognitive processes (Sopory & Dillard, 2002). Thus the distinction between these two terms is problematic, and for the sake of clarity, they are treated here synonymously.

Advance organizers

Advance organizers have been studied in the context of education psychology and education research. It is a communication technique to provide structure to information that is presented to an audience that may have some or no knowledge of the concepts being discussed. Advance organizers are routinely created and encountered by average people. Such organization can include visual tools such as titles, headings, and subheadings; or they can be verbal like an introductory statement in a speech that explicitly tells the audience there are a certain number of main points that will be presented. Advance organizers serve as frameworks to enable learning of information and create meaningful links between ideas, and have been shown to improve recall, motivate learners, and enhance understanding in science education (Mayer, 1979; Mayer, Dyck, & Cook, 1984; Shihusa & Keraro, 2009).

Regarding the structure of a metaphor, with its two main components (i.e. base and target), metaphors follow a set structure and are considered to be advance organizers (Ausubel, 1960; Ivie, 1998). Metaphors share common characteristics with advance organizers which include generating logical relationships among new and old concepts, influence an individual's conceptual encoding process, and provide a foundational concept that an individual has knowledge of which is then used to assimilate new material (Mayer, 1979). An advance organizer creates cognitive bridges, providing structure for learning processes to take place and link known material with what is being learned (Novak, 1980). An example of a metaphor as an advance organizer could be outlining the process of osmosis. The process of objects being moved from one side of a scale to the other can be outlined in parallel with molecules moving across a semi-permeable membrane from a region of higher concentration to a region of lower concentration of water molecules to equalize concentrations on either side of a membrane. Such comparisons can create a clear connection for each step of the process of a complicated concept.

Bridging

Bridging rhetoric can be an important concept for a communicator when considering reaching out to distinct and diverse audiences. Bridging helps to represent an idea in one's discourse and make it compatible to another's discourse (Dryzek, 2010). This notion can employ the use of metaphor, though metaphor is but one contributor to bridging rhetoric. A speaker could use other framing techniques to facilitate a dialog in which the speaker demonstrates how the speaker shares the audience's problems and remedies (Kuypers, 2009). Bridging, like metaphor, can be used as an explanatory and/or persuasive communication device (Dryzek & Lo, 2015; Sopory & Dillard, 2002). One example of bridging that has been demonstrated by environmentalists is using rhetoric to invoke "God's creation" rather than "the environment" (Dryzek, 2010). This has been done in an attempt to expand environmentalists' audience to Evangelical Christians, and form a bridge between "liberal environmentalists" and "conservative Christians." Thus, this approach uses relatable, and familiar concepts to reach a new audience and facilitate acceptance of a new or different idea.

Dryzek and Lo (2015) framed a solution to climate change as Medicare for the climate. They found that those skeptical of climate change were more assured regarding public funds and policy regarding greenhouse gas reduction, and trust in institutions to follow through with such climate mitigation policies after dialogue that incorporated this frame. Using bridging rhetoric in such a way "invoked an established system which has gained public trust over the years and of which the participants had shared experience" and resulted in the agreement of participants to "join in a collective problem-solving process" (Dryzek & Lo, 2015, p. 12). While skeptics in the end would participate in a mandate to reduce greenhouse gases, their stance on the science of climate change being uncertain did not change. This approach made the concept of mitigating climate change relatable and leveraged a metaphor. However, the metaphor was used to initiate and shape the conversation so that two sides, those opposed and those in support of greenhouse gas reduction mandates, saw that there was common ground on which they could make decisions, such as to accept and support a policy or not.

Concept maps

Concept mapping is a way of diagramming the ways in which one concept is related to another. It is more formally defined as a tool that "organizes knowledge into a hierarchical structure in which subordinate concepts are subsumed under superordinate concepts" (Willerman & Mac Harg, 1991, p. 707). Such a tool is often used in an educational setting as a learning tool and as a way to evaluate learning processes. An example of a concept map could demonstrate how the terms mammal and amphibian are related to primate – the main common concept of all the terms is the Kingdom Animalia (Figure 3A). A test question may prompt students to also draw a diagram to conceptually demonstrate the relationships between climate, temperature, precipitation, location, seasons, and atmospheric circulation (Figure 3B). Hence this is a visualization technique to illustrate conceptual relationships. In this way, concept maps overlap with metaphors and advance organizers, and help students understand and organize information by making connections between concepts (Willerman & Mac Harg, 1991). They provide, particularly in education, a way to generate meaning, elaborate on existing frameworks, and modify frameworks where misconceptions need to be corrected (Novak, 1980).

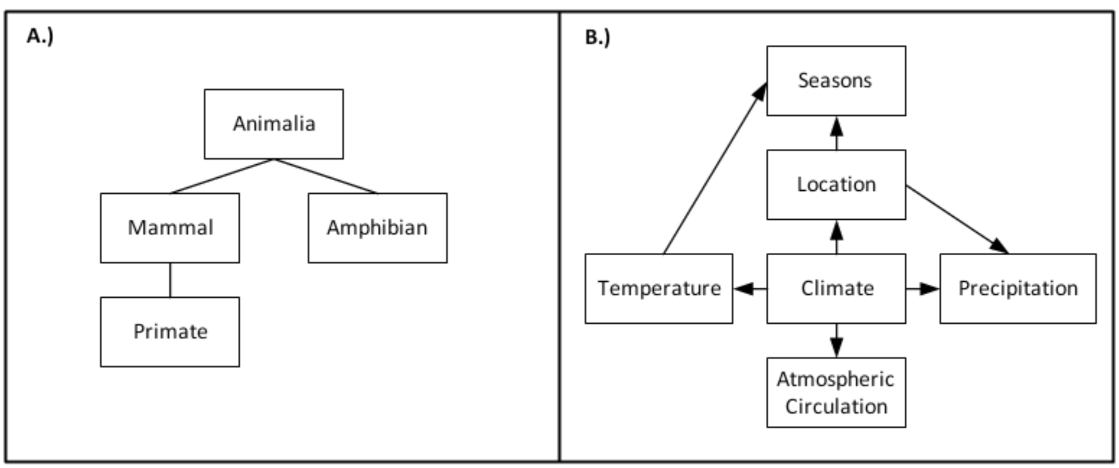

Figure 3. Concept maps.
The example concept maps depict: A) relationship of primate to mammal and amphibian, and B) temperature climate, temperature, precipitation, location, seasons, and atmospheric circulation.

However, concept maps are unlike metaphors in that they do not typically appear in traditional encyclopedia entries or news feature stories. Instead, they are tools students and teachers make to assist in the learning process, and in the examples provided, specific science concepts (McClure, Sonak, & Suen, 1999). In a classroom, concept maps can be used to assess what relationships students are making between concepts they are learning about (e.g. vascular and non-vascular plants), and whether the connections are accurate or not (Rice, Ryan, & Samson, 1998). Students who were taught with concept mapping, mapped more relationships and performed better on science aptitude tests than those who were not exposed to concept mapping (Novak, 1980; Novak, Bob Gowin, & Johansen, 1983).

Another difference between metaphor and concept mapping is that concept mapping focuses on relationships within a discipline or concept (e.g. the relationships of the components of a clock) (Stewart, Van Kirk, & Rowell, 1979). This is as opposed to drawing comparisons between a familiar discipline or concept and an unfamiliar, unrelated concept. In other words, analogical (conceptual) mapping should not be confused with the conceptual mapping process, which occurs with the usage of metaphor: "the correspondences between elements of source and target domains in conceptual metaphors" (Semino, 2008, p. 226). Analogical mapping can be observed in Figure 2 above where the features of a familiar concept are mapped to the features of the unfamiliar concept, and compared to concept maps in Figure 3.

Mental Models

Mental models are archetypes of an individual's thought processes that help them shape their perceptions and understandings of how things work in the world. These could be accurate or inaccurate, and can demonstrate the disconnect between reality and fantasy, as well as the differences between expert knowledge and non-expert knowledge (Morgan et al., 2002). The notion of mental models developed as a result of cognitive scientists wanting to better understand perspectives of experts and lay audiences, and identify those differences. Mental models create descriptions and summarize vital concepts, making concepts easier to grasp and in some cases assess risk (Morgan et al., 2002), similarly to metaphors. An individual's mental models are formed based on experiences, so they are accessed when processing new information and activate experiential processing to ease understanding and applicability of new information. Contextualizing new information in what someone already knows reduces the cognitive load, and therefore can help in the understanding of complex concepts.

Mental models are considered to be personal while metaphors are shared within a community (Duit & Glynn, 1996). While mental models and metaphor are considered independent of each other, there is a strong relationship between the two. Mental models and metaphors are related because each facilitates the interpretation of "the flood of stimuli and information that our brains absorb from the world around us" (Zaltman, 2003). It has been demonstrated that metaphors can be an outcome, or build off of mental models. Morgan et al. (2002) study mental models particularly in situations involving risk. Researchers access individuals' mental models by asking questions like "what causes cancer?" and "why is climate change occurring?" In eliciting mental models in interviews about risk and the natural world, metaphors can be generated or identified through how people judge, recognize, interact, and deal with abstract complexities. Mayer (1993) described how both mental models and metaphors can be used to help students understand scientific concepts. There are three levels of mental models that students reach: 1) zero-order qualitative – basic, superficial understanding; 2) first-order qualitative – more detailed connections between concepts; and 3) quantitative model – demonstrating numeracy or the ability to understand and work with numbers (Mayer, 1993). Since metaphors in particular help make connections between concepts and can elaborate on explanations of different concepts, they have the potential to help an individual make the transition from the first to the second and third levels mentioned above.

2.2 Operational Analysis

The consequences of the use of metaphors have been operationalized through measures of effectiveness. These outcome measures depend on the motive and purpose of metaphor usage. The measures have included, but are not limited to, comprehension, concept feature mapping, application, and preferences for action or solvability of a problem. Researchers have used several approaches to evaluate and measure the effectiveness of metaphors with non-expert audiences. Qualitative methods include interviews, classroom observation, and persistence trials. Another method involves quantitative framing and message testing experiments through surveys. Some researchers have taken mixed methodology approaches to studying the effects of metaphors, while others have selected to focus on just one technique.

Qualitative methods

Qualitative methods can assess the impact of metaphor and identify useful metaphors. Interviews that examine individuals' mental models or elicit metaphors provide insight to researchers about how people make sense of complex concepts, and what associations might be made between different concepts (Morgan et al., 2002; Zaltman, 2003). Interviews provide an opportunity to find out what people know or do not know already before and after exposure to a metaphor. Follow up questions aim to ascertain if participants demonstrate a better understanding of the concept, if they can apply anything that may have been new or to correct misconceptions, and if the second round explanations by the participant are more detailed and perhaps articulated at a higher level (Kendall-Taylor et al., 2013). Others have also probed to see if interviewees would think about and discuss actions that could be taken or solutions that could solve a problem after being exposed to explanatory metaphors (Volmert, 2014). For example, Volmert (2014) found in conducting street interviews and testing several different climate metaphors, some clearly resonated better than others. One metaphor that was named "osteoporosis of the sea" to explain the effects of ocean acidification generally worked well, but the connection between carbon dioxide and ocean acidification was unsuccessful. These studies were set up so that the results of these studies would inform follow-up message testing treatments. A metaphor that was developed as a result of a series of interviews, which was later tested in a survey, was the "climate's heart" metaphor and explains how the ocean plays a substantial role in regulating the climate system (Volmert, 2014). This demonstrates how new and additional metaphors can be uncovered through qualitative interviews.

Studies of the effectiveness of metaphor have also been observed in a classroom setting with teachers and students (Aubusson et al., 2006; Glynn & Takahashi, 1998; Guerra-Ramos, 2011). The use of metaphor has been evaluated for understanding and comprehension, memory, motivation, and confidence that the student can learn new material. Other qualitative observations that can be made include the correction or perpetuation of misconceptions. Such observations were made during discussions between students and teachers about the concept introduced with a metaphor.

Persistence trials "examine how well the explanatory metaphor holds up when being 'passed' between individuals, and how participants use and incorporate metaphor in subsequent explanation to other participants" (Kendall-Taylor et al., 2013). During the transferring of information from the researcher through the three groups back to the researcher, observations are made whether the metaphor was able to be used repeatedly or if it 'died' (wasn't used) over time; if the information remained correct or accurate; if it corrected misunderstandings; and if there was consistency in the language used (Kendall-Taylor et al., 2013; Volmert, 2014).

Quantitative methods

The effectiveness of metaphor can be assessed quantitatively using experimental methods. A series of survey questions pre- and post-exposure to a metaphor can measure various levels of effectiveness of metaphors. Outcome measures have included knowledge or understanding, application, and preference for actions or perceived solvability of a problem after a participant has read a passage that uses a metaphor (Kendall-Taylor et al., 2013; Volmert, 2014). In testing eleven different climate change and ocean impacts metaphors, Volmert (2014) found that all metaphor conditions significantly increased survey participants' knowledge by 6.4 percentage points when compared to a control (no metaphor) condition. Guy, Kashima, Walker, and O'Neill (2013) observed that increased concept feature mapping was associated with a preference for strong climate action when testing the "carbon dioxide bathtub" metaphor – comparing the correlated increases in atmospheric carbon dioxide and global temperature to a bathtub filling and overflowing with water. However, the understanding of the phenomenon of accumulating carbon dioxide was not found to significantly contribute to action preference. When aiming to increase an individual's perception of scientific consensus on climate change, metaphors have been shown to be effective, but not as effective as a pie chart or descriptive text (van der Linden et al., 2014).

2.3 Mediating Factors

The effectiveness of metaphor can be influenced by an individual's familiarity with the base and target, an individual's initial attitude towards and involvement with metaphor topic components, and the position of the metaphor in a message.

Familiarity

Familiarity with the base can influence effectiveness of a metaphor. Familiarity is the amount of accumulated experience with a specific concept and varies from person to person. Researchers also have measured familiarity as the state of having knowledge of or ease of understanding something (Bettman & Park, 1980; Feiereisen et al., 2008). Since the base of the metaphor is the concept that contextualizes the target you are trying to communicate about, familiarity is key. If there is a lack of familiarity for the base, the comprehension of the target diminishes (Guerra-Ramos, 2011), the metaphor's effectiveness is reduced (Hoeffler & Herzenstein, 2011), and can lead to misinformation (Gentner & Markman, 1997). Similar trends have also been shown for target familiarity. Higher levels of target familiarity have been shown to have greater persuasive power and therefore metaphor effectiveness (Sopory & Dillard, 2002). Familiarity of a metaphor as a whole also influences the processing of a metaphor's content. The more familiar the metaphor and its components are, the better the comprehension (Blasko & Connine, 1993).

Initial attitude and involvement

Recipients' initial attitude and involvement with the target topic of the metaphor can affect metaphor's effectiveness. If attitudes towards metaphor content is positive (or negative) initially, then the results tend to be positive (or negative), respectively (Lakoff & Johnson, 2003). A message using a metaphor will likely resonate more or less due to an individual's preferences, interests, or involvement. Ottati, Rhoads, and Graesser (1999) found that when a sports metaphor was used to persuade individuals that a senior thesis is necessary, those that enjoy sports were more receptive to the idea than those who disliked sports.

Position in passage

The positioning of a metaphor in a passage can also influence the effectiveness of a metaphor. In a message explaining a concept a metaphor can come at the beginning, middle, or the end to drive home a point. The earlier a reader or listener encounters a metaphor, the more persuasive the metaphor will be (Sopory & Dillard, 2002). This is perhaps because having a comparison sets the tone or theme of the passage, and can then foster more similarities (and differences) throughout the remaining portions of the message for a complete picture of the initially unfamiliar concept. Metaphors placed at the beginning of a passage may also serve as an advance organizer, and aid in learning and remembering material (Mayer & Bromage, 1980; Mayer et al., 1984).

2.4 Consequences of Using Metaphors

Metaphors have been shown in some studies to enhance learning among individuals who are novices or non-experts in a specific domain, including better or increased comprehension, understanding, and recall of information. In some studies, communicating with metaphors has also been shown to enhance perceived source credibility. As implied above, however, other studies have shown either mixed or no effects of metaphors. The following section elaborates on the effects of using metaphor to communicate in a variety of domains.

Comprehension, understanding, and recall

Metaphors have the potential to improve understanding and comprehension, and enhance recall commonly difficult concepts. Overall, the results of such studies examining if there are positive effects of metaphors on comprehension, understanding, and recall vary.

In the science education domain, researchers have studied how metaphors can be beneficial to students learning new concepts in a classroom setting (Guerra-Ramos, 2011). Glynn and Takahashi (1998) conducted two experiments, one with eighth graders and another with sixth graders to examine understanding and recall of a metaphor that compares how a cell's functions relate to a factory. Students were asked to respond to open-ended questions about how a cell works after reading the explanatory passage, and then again two weeks later. The students receiving the metaphor condition performed significantly better immediately after and two weeks later than the control condition: understandability ratings were significantly higher. They recalled the metaphor comparing the cell to the factory, and made more correct connections between the base and target than did the control group (Glynn & Takahashi, 1998). However, in another metaphor study comparing photosynthesis to baking a cake, results did not find understanding or recall to be enhanced with most students, without the guidance of the instructor (Mason, 1994). This demonstrates what Guerra-Ramos (2011) notes as a metaphor "breaking down." In the case of the photosynthesis metaphor, nearly a third of the students appeared confused and incorrectly mapped the raw and end products between the base and target concepts (Mason, 1994).

The comprehension benefits of metaphor have been studied in other domains, such as advertising and health risk communication. Ait El Houssi et al. (2004) demonstrated both explicit and implicit analogies (conceptual metaphor) used in an advertisement benefits comprehension of a new product more than ads with literal similarity. Galesic and Garcia-Retamero (2013) examined how message recipient's numeracy influences the effectiveness of metaphors developed to explain easy (medical screenings) and difficult (medical treatments) to understand medical problems. They found that metaphors were helpful to high-numeracy people for understanding difficult medical problems. For low-numeracy people though, metaphors were helpful for conceptually easy medical problems but were not helpful for difficult medical problems.

Source credibility

Metaphor has the potential to enhance perceived credibility of messages and the messengers. In a literature review, Sopory and Dillard (2002, p. 385) explained that "the communicator credibility view proposes that communicators who use metaphors are judged more credible than ones who use literal language (Bowers & Osborn, 1966; McCroskey & Combs, 1969; Osborn & Ehninger, 1962; Reinsch, 1970)." A reason metaphor may instill a sense of credibility, or trustworthiness in a message and a messenger is that "it is the realness, or the ready relation to one's experience of reality, that allows the material not to require justification because it is witnessed as already trustworthy or valid" (Selin, 2006, p. 10). The familiarity of the base can set the tone, grounding the metaphor in something the message receiver already knows and trusts. Furthermore, "metaphorical language functions as a simple, heuristic cue that signals the source is highly intelligent and credible" (Ottati & Renstrom, 2010, p. 786). However, in Sopory and Dillard's (2002) meta-analysis, only one dimension of credibility – dynamism – was found to be significantly increased; overall metaphor did not prove to influence post-message credibility. However, this is not to say that there is a complete lack of a relationship between the use of metaphor and communicator credibility when assessing metaphors for specific domains.

Persuasion

Metaphor has been used as a persuasive technique in contexts of politics and policies (Dryzek & Lo, 2015; Graesser, Mio, & Millis, 1989), risk communication (Krieger, Parrott, & Nussbaum, 2010), and consumer advertising (Boozer, Wyld, & Grant, 1990; Roehm & Sternthal, 2001), to name a few. Regarding policy, using a metaphor allowed for common ground to be found between opposing sides of a greenhouse gas reduction policy, and resulting in those initially in opposition to become more willing to support the policy to collectively solve a problem (Dryzek & Lo, 2015).

Metaphors have been shown to be a powerful communication device with regards to persuasiveness for new products (Roehm & Sternthal, 2001). The product metaphors were more persuasive for product experts who were familiar with products than non-experts. However in additional experiments that included prompting of a positive mood surrounding the product, the persuasiveness of the product metaphor increased significantly for non-experts as well. In risk communication, particularly related to health, metaphors have had mixed results when attempting to persuade an audience. Krieger et al. (2010) used a cultural metaphors which motivated older and lower income women to participate in a clinical trial, while other studies have found metaphors failed to promote positive decisions about medical treatments (Snowdon, Garcia, & Elbourne, 1997).

2.5 Limitations to the Effectiveness of Metaphors

Metaphors provide a means to make concepts more cognitively approachable and manageable, increase the usability of information, and reduce concern about abstract uncertainty. However, there are limitations to using metaphor to more effectively communicate, particularly for science and climate change. A significant barrier that can limit the effectiveness of metaphor is the audience's familiarity with the base concept, and secondarily the target concept. Avoiding conduit metaphors – metaphors that lack context – and using base concepts that the audience is familiar with should help in countering this limitation (Lakoff & Johnson, 2003). Metaphors also have the potential to "break down" due to factors like: crucial dissimilarities, oversimplification, or being overly complicated (Guerra-Ramos, 2011). As with any major issue, when creating metaphors for climate change, it is possible to overcompensate by evoking too much emotion or worry. There is evidence that there is a finite pool of worry (Hansen, Marx, & Weber, 2004). In other words people have a capacity limit for worry. With this in mind, metaphors should limit increasing concern for one risk and reduce concern for another risk potentially causing a single action bias (Marx et al., 2007; Weber, 1997). Such factors put concepts in danger of being ignored, miscomprehended, features being translated incorrectly, and confused with another concept, defeating the purpose of a metaphor whether it be for one or a combination of understanding, application, or motivation.

Metaphor development and testing is often trial and error. While metaphors do tend to work better than literal language, empirical studies have shown mixed results. As discussed throughout this chapter, the effectiveness of using metaphors appears to be very context, content, and audience specific. Much care and attention should be taken when developing metaphors, and perhaps include multiple rounds of testing before using a metaphor. For example, Glynn & Takahashi (1998) observed measurable success in terms of recall of information, while Mason (1994) found students required additional guidance from their instructor to recall the concept taught using a metaphor. Additionally, Sopory and Dillard's (2002) meta-analysis also suggests that communicator credibility does not always improve with the usage of metaphor, though others suggest otherwise in specific cases (Selin, 2006; Ottati & Renstrom, 2010). Hence examining communicator credibility after using an explanatory metaphor in specific contexts is worthy of investigation.

2.6 Research Questions and Hypotheses

A number of important, well-established concepts in climate science are potentially useful in terms of understanding the reality of climate change and need to take action. Yet many of these concepts are currently either unknown, misunderstood, or ignored by many Americans. As noted previously, although research on the effectiveness of metaphors has shown mixed results, appropriate use of metaphor has potential to improve the communication of important climate change concepts by making them more understandable, and relatable. As climate science concepts have a range of conceptual complexity, identifying familiar concepts and features can help explain unfamiliar scientific concepts. Activating experiential information processing to aid the understanding of a more complex concept, which would require more analytical information processing, can be beneficial. For these reasons, climate change metaphors are ripe for investigation as a tool for scientists to use when communicating to non-expert audiences.

Research questions for Study 1 and Study 2

Expert and non-expert mental models

Mental models of experts and non-experts can help illustrate how individuals understand complex concepts, situations, and risk. Finding out what these mental models are can help a communicator design messages that incorporate how experts and non-experts make sense of concepts, what experts think non-experts should know, and what non-experts know and do not know already. Mental models can lead to eliciting and developing metaphors, and address both what people need to know but don't already (Morgan et al., 2002). Researchers have demonstrated that non-expert Americans have a limited understanding of climate change regardless of the Global Warming's Six Americas audience segment (six unique audiences within the American public that each responds to the issue in their own distinct way based on the strength of their beliefs, concerns and motivations), and about half receive a failing grade based on a series of climate change knowledge questions (Leiserowitz et al., 2010). This lack of understanding, or misconceptions about climate change hinders their ability to make productive decisions and perhaps take proactive action towards mitigating and/or adapting to the effects of human-induced climate change. In such a scenario Morgan and colleagues (2002) recommend taking several steps to develop effective messages for non-experts: 1) review expert literature to develop messages, 2) validate the constructed expert model with technical experts, 3) examine non-expert mental models, 4) compare expert and non-expert mental models, 5) construct a single description for each concept(s), and 6) test messages developed based on the information gathered. I used this protocol to explore the following two research questions as formative research to identify the most promising metaphors to examine in a message testing experiment:

RQ1: *What metaphors do experts use and find effective to explain different climate change concepts to lay audiences?*

RQ2: *Is the science in the originally drafted stimulus materials accurate and explained using valid and usable metaphors?*

RQ3: *How do lay audiences currently make sense climate change and related concepts?*

RQ4: *How do lay audiences react and process climate change information when presented with explanatory metaphors?*

Research questions and hypotheses for Study 3

Are metaphors more effective than literal language?

Numerous studies have had varying levels of success regarding the effectiveness of metaphor when compared to literal, non-metaphor conceptual explanations. Sopory and Dillard's (2002) meta-analysis demonstrates that metaphors, and more specifically novel metaphors, resonate better with individuals when it comes to persuasive power and understanding than conduit metaphors, or literal language. Metaphors in comparison to literal language have had both positive and negative effects on non-expert's knowledge in a variety of contexts and for different reasons (Ait El Houssi et al., 2004; Galesic & Garcia-Retamero, 2013; Glynn & Takahashi, 1998; Guerra-Ramos, 2011; Mason, 1994; Roehm & Sternthal, 2001). These findings in part provide motivation to test if there are differences in the effectiveness of climate science explanations both with and without metaphors.

Recent investigations have examined how explaining climate change in a specific way may influence the understanding of climate change and the belief in whether climate change is real and human caused. This is of interest because a lack of belief certainty that climate change is real and human caused may be a result of a lack of understanding of the complex science involved. A series of studies considered the effects of a mechanistic explanation of climate change on climate change attitudes and knowledge (Ranney & Clark, 2016; Ranney, Clark, Reinholz, & Cohen, 2012). In testing a brief explanatory statement (400 words) that organized the greenhouse effect into three sequential mechanisms, essentially using an advance organizer message strategy, understanding of climate change and the willingness to accept climate change, as real and anthropogenic were statistically significant. These results, and the potential that metaphors can positively influence knowledge leads to additional research questions:

> **H1:** *The combination of science and metaphor to explain a climate change concept will lead to favorable changes in individuals' understanding; and metaphor or science alone will result in a less favorable change in understanding. (S+M > M > S)*
>
> **H2:** *The combination of science and metaphor to explain a climate change concept will lead to favorable changes in individuals' belief certainty that climate change is happening; and metaphor or science alone will result in a less favorable change in belief certainty. (S+M > M > S > C)*

Familiarity effects on metaphor outcomes

In explicating metaphor usage, a key potential mediator of the effectiveness of metaphors was the familiarity with the base and target concepts of a metaphor. In creating, testing, and using metaphors to communicate climate change, exploring the function of familiarity can prove to be beneficial. Familiarity, particularly of the base concept of the metaphor, is important because if there is a lack of familiarity for the base, comprehension of the target diminishes, and thus the effectiveness is reduced and misinformation or confusion can be generated (Gentner & Markman, 1997; Guerra-Ramos, 2011). Higher familiarity with concepts intuitively leads to more persuasion and understanding of a concept, as reviewed in a meta-analysis by Sopory & Dillard (2002). Though the overall conclusion was that those with high familiarity showed greater persuasion than individuals with low familiarity was non-significant, the trend was that metaphors in comparison to literal language were beneficial to learners was apparent. Since other studies have demonstrated familiar bases and targets influence the effectiveness of messages using metaphors (Blasko & Connine, 1993; Galesic & Garcia-Retamero, 2013; Guerra-Ramos, 2011; Ottati et al., 1999), the same pattern may apply for climate change concepts. Therefore it is hypothesized that:

H3a: *The more familiar the* ***base*** *concept is, the more effective the inclusion of a metaphor will be in improving understanding of the concept.*

H3b: *The more familiar the climate science concept (****target****) is, the less effective the inclusion of a metaphor will be in improving understanding of the concept.*

CHAPTER 3. STUDY 1 – EXPERT REVIEW & VALIDATION OF CLIMATE SCIENCE EXPLANATORY METAPHORS

3.1 Introduction

In-depth interviews of experts can help illustrate – from an expert's point of view – how individuals understand complex concepts, situations, and risk. Understanding expert perspectives can help a communicator design messages that incorporate how experts make sense of concepts, what experts think non-experts should know, and how and why experts use explanatory tools when communicating with lay audiences. Mental models can also lead to eliciting and developing metaphors (Morgan et al., 2002). To develop effective messages for non-experts Morgan and colleagues (2002) recommend taking several steps, the first two of which are to 1) review expert literature to develop messages, and 2) validate the constructed expert model with technical experts. This chapter details the expert review and validation of four explanatory passages using four different metaphors each tailored to a specific climate science topic.

Objectives

Given the null results of the pilot study, consulting expert advice and validation of the original stimulus material would be one step towards an improvement in the message testing study design. Subjecting the materials through a technical expert review aims to ensure that the written material to which non-experts will be exposed to at a later time is accurate, and contributes towards a more complete expert model (Morgan et al., 2002).

Incorporation of expert interviews has allowed for: suggestions for the passages, a better understanding of expert explanations the four concepts, and discovery of additional metaphors and knowledge of the concepts. This study is an exploratory study and aims to answer the research questions:

> ***RQ1:*** *What metaphors do experts use and find effective to explain different climate change concepts to lay audiences?*
> ***RQ2:*** *Is the science in the originally drafted stimulus materials accurate and explained using valid and usable metaphors?*

Expert elicitation and defining experts

Eliciting expert knowledge employs structured or semi-structured interviews to gather and evaluate subjective knowledge and perspectives of experts (Morgan, Henrion, & Small, 1992; Wright & Ayton, 1987). The interview protocol includes open-ended questions followed up with more targeted questions for clarification. While this method can help identify future research needs, and capture the range of agreement and disagreement within an expert community (Hagerman, Dowlatabadi, Satterfield, & McDaniels, 2010), there are also some limitations to the method. It is important for interview questions to be refined in order for the questions to be clear and have the same meaning for the researcher and interviewee. If the questions are not clear, the participant might not understand the question or provide a response that is not relevant to the intended question. To avoid this problem, Morgan, Pitelka, and Shevliakova (2001) recommend running a pilot test and clearly stating the purpose of the study. For this study, when experts were initially contacted the purpose of the study was described and any questions the expert had about the study were answered promptly.

In the expert knowledge elicitation literature, the definition of what constitutes an expert is relatively fluid with no clear consensus on what criteria is required to be identified as an expert (Lowe & Lorenzoni, 2007). Some researchers have defined characteristics of experts to include the ability to arrive at a decision differently from a non-expert using cognitive heuristics (Slovic, 2000) while others have identified an expert as an individual who has studied a subject intensely (Krayer von Krauss, Casman, & Small, 2004). When investigating experts' perceptions for managing climate change impacts, Lowe and Lorenzoni (2007) defined experts as individuals who are able to form well thought out opinions based on their experience and knowledge in a particular field. For the purposes of this study, experts were defined using similar requirements that Nordhaus (1994) and Cooke and Goossens (2004) used. Individuals who participated in an interview were selected based on expertise (education, knowledge, publication) in natural sciences relevant to climate change, and known to have experience and interest in communicating with lay audiences about climate change. More details about the participant studies are presented in the methods section.

Expert opinions, perspectives, and expertise have been called upon for numerous reasons related to climate change. Experts have been consulted by researchers to fulfill roles in improving decision support tools, informing policy, and obtaining a better understanding of environmental risks and how scientists recommend managing those risks. Experts have been consulted to understand their recommendations for managing dangerous climate change (Lowe & Lorenzoni, 2007); successfully adapting to climate change (Doria, Boyd, Tompkins, & Adger, 2009); analyzing implications of climate change for conservation policy (Hagerman et al., 2010); and studying challenges forest ecosystems will face if carbon dioxide concentration were to double (Morgan et al., 2001). This first study of my dissertation is focused on the elicitation of expert opinion on how four different climate science topics are explained using metaphors. The elicitation process of expert knowledge and views consisted of semi-structured interviews where experts were asked a few introductory questions about their experiences communicating with lay audiences and using metaphors followed by reading and discussing four explanatory essays containing climate change concept metaphors.

3.2 Methods

Sample

This study recruited via email 18 climate science experts who regularly perform some combination of formal (i.e. teaching, conference presentations) and informal (i.e. blogging, public presentations/lectures) climate science communication. Five of the 18 individuals were contacted based on recommendations from either an initial contact who was unavailable or declined to participate; or from a participant who completed an interview. Of those contacted, 12 agreed to and completed an interview in-person or on Skype. Each participant received and signed a written consent form prior to participation; steps approved by the Institutional Review Board (IRB) at George Mason University. All participants were assigned a number to maintain anonymity, held advanced degrees (MS or PhD), spent numerous years working in their field of expertise, and more than 10 years conducting science outreach and communication (Table 1). Of the experts interviewed, eight were male and four were female.

Table 1. Experts interviewed in this study.
Experts are listed by their assigned participant number with highest degree held, main areas of expertise, sector(s) in which the currently are employed, and roles in their organization.

#	Degree	Main Area of Expertise	Sector	Current Role
1	PhD	Geophysical Fluid Dynamics	Higher Education	Professor
2	PhD	Meteorology	Higher Education	Professor
3	PhD	Geology	Higher Education	Professor
4	MS	Science & Education	Government	Science Education Coordinator
5	MS	Geological Oceanography	Government	Regional Climate Services Director
6	PhD	Applied Physics, Atmospheric Dynamics	Higher Education	Professor
7	MS	Marine Resource Management & Oceanography	Government	Public Affairs Specialist
8	PhD	Natural Resources	Government & Higher Education	Principle Climate Change Scientist
9	MS	Marine Science	Government	Senior Science Editor
10	PhD	Astrophysics	Government	Deputy Dir. of Science Communication
11	MS	Meteorology	Government	Chief Scientist
12	PhD	Public Communication & Technology	Non-government Organization	Project Atmospheric Scientist

Interview design and procedure

All interviews were conducted between January and March 2016, and took an average of 74 minutes (ranging from 55 to 105 minutes). The interviews were semi-structured, and designed to elicit expert views on climate science concepts presented and explained using metaphors. Interviews were divided into three parts: an overview of the experts background, experience with non-expert audiences, and their usage of metaphors when explaining climate change concepts; evaluation and validation of four short essays; and concluded with final thoughts and any further suggestions for consideration (A.1 – Study 1 Interview Guide). The core of the interview primarily focused on reviewing four short explanatory essays; and secondarily examined how experts explain each of the four concepts before and after reading the passage, including other metaphors.

Each of the essays explained one of four climate change topics and incorporated a metaphor into the explanation of the topic (See appendix A.2 – Study 1 Stimulus Materials for Expert Review). The four topics were: 1) the frequency of extreme weather events; 2) the rate at which carbon dioxide is increasing; 3) the enhanced greenhouse effect; and 4) the difference between weather and climate. Respectively, the metaphors were: 1) the frequency of homeruns hit by a baseball player on steroids; 2) the rate at which water enters and exits a bathtub; 3) the effect on the interior temperature of a parked car in the summer sun; and 4) baseball statistics – the outcome of a baseball player up at bat and his batting average. The essays were between 520 to 650 words. Each consisted of a title phrased as a question, a short introductory paragraph followed by science-based information, a short metaphorical explanation, more of a science-based explanation, and concluded with a summary paragraph.

Prior to reading the first essay, participants were provided with orange and pink highlighters. Each was asked to use orange to highlight what they liked, found to be accurate, or clearly written; and to use pink to indicate what was disliked, found to be inaccurate, or unclearly written. After reading each essay, experts were asked about their overall thoughts related to the explanatory essay in order to obtain a general, initial reaction to the essay before talking in-depth about what was specifically highlighted. The interview then focused both on the reader's reasoning behind highlighting sentences, phrases and words orange in either orange or pink. Alternative explanations, metaphors, explanatory techniques, and substitute terminology were discussed as well for a more in-depth understanding of the expert reactions and overall feedback on the content of the essays.

Coding and analysis approach

All 12 interviews were audio-recorded and transcribed verbatim. Following a similar procedure found in Maibach, Nisbet, Baldwin, Akerlof, and Diao (2010), sentence-specific reactions for each of the four passages were coded based on highlighting color. Sentences, phrases or words highlighted in orange were assigned a score of +1, thus indicating the sentence was liked, accurate, or clearly written. Conversely, any text marked in pink was assigned a score of -1, indicating the sentence was disliked, inaccurate, or unclear. If no highlights were made, the sentences were scored 0. A spreadsheet was used to keep track of specific phrases and words that were highlighted if the full sentence was not highlighted. From these scores, average scores were calculated for each passage per expert, each passage overall, the metaphor paragraph overall, and the science paragraphs overall. To test if the median response to the essay, metaphor paragraph, and science paragraphs scores were greater than zero (i.e. a positive reaction) for the full sample, the Wilcoxon signed rank test was used. The Wilcoxon signed rank test was also used to test if there was a significant difference in reactions between the metaphor and science sections of each essay. This test was appropriate here due to the small sample sizes and non-normal distributions of the data. Additionally, the transcripts were reviewed and coded for common themes and ideas. Due to the exploratory nature of the interviews, the feedback was used to improve the stimulus materials (essay passages), and the coding was primarily data-driven, based in grounded theory (Charmaz, 2006). Ultimately three thematic categories emerged from the statements made by the experts. These categories are elaborated upon in the results section of this paper.

3.3 Findings and Discussion

The experts who participated in this study were enthusiastic to discuss their experiences communicating with lay audiences as well as evaluating the explanatory climate change metaphors, i.e. the central focus of the interview. The results presented here first include an overview of how these experts approach communicating with non-expert audiences and use metaphors to explain climate change concepts, or why they may choose not to use metaphors. Quantitative and qualitative analyses were then applied to the more specific reactions captured in the interviews to each of the four essays read and subsequently discussed. The reactions to the four essays were observed quantitatively through scoring the sentences based on the highlights made by each expert. The quantitative analysis approach provides a snapshot of instant reactions to the essays overall, as well how the metaphors, and the science components were performed individually and in comparison to each other. The qualitative analysis provides several insights into the experts' evaluation of the essays and metaphors including a deeper understanding of the highlights in terms of why essays, or essay components, were viewed either positively or negatively. Additionally reasons why a particular metaphor may or may not be commonly used, suggestions for improvements for scientific accuracy, and alternative metaphors or explanatory techniques used for explaining particular climate change concepts were revealed.

Experiences with lay audiences

Each interview session commenced with gathering some background on the subject matter expert's current position and organization, and degrees received (Table 1). Additionally, the experts were asked to briefly discuss their experiences with and approaches to communicating with lay audiences. Experiences with non-expert audiences included talking with elementary school students, giving lectures (as a main professor or guest speaker) in undergraduate and graduate courses as well as presenting to local garden clubs, and insurance agencies. There was a clear consensus that knowing your audience truly matters. Participants 3 and 5 particularly alluded to the importance of tailoring talks to the age group of the audience (e.g. adults vs. children):

> *Participant 3: And then I'll say I'll get to the attributions side of things that and that's the kind of IPCC general statement and if it's an educated audience I'll use words like the preponderance of evidence suggests this. If I'm talking to kids, a whole bunch of things point to.*

> *Participant 5: I generally talk to an adult audience, which is different than in the past when I've talked with kids.*

One expert even explained that when they are talking specifically about weather and climate, they change the metaphor they use for different audiences based on age, or whether or not they know their audience consists of sports fans:

Participant 11: [Metaphors that have] worked well are the relationship between weather and climate being this coach-athlete, trainer-boxer, parent-child, mentor-apprentice kind of relationship... If they're really old, which I mean my age or older, I'll use my son actually as a living metaphor so I'll have a poster of Beaver Cleaver from the Leave it to Beaver show and Ward Cleaver on the other side, and I'll talk about my son being a teenage boy. He's impulsive, he's quick to react, he's really sensitive to his environment but in a beautiful way he forgets things and moves on and if I haven't named something else I would have named him weather... We'll use a LeBron James [and his basketball coach] for the younger kids... If I was talking to my mom's herb club, you know I'd probably pick a different metaphor.

In discussing the usage of metaphors when communicating with a non-expert audience, only half of the experts interviewed initially remembered a metaphor they had used in the past, had heard a colleague use, or read an article about climate change that used a metaphor. However later in the interviews and after reading the essays, all but two offered independently or when prompted suggested alternative metaphors (see list in Appendix - A.3 – List of expert-generated metaphors from interviews). Regardless of having used or initially remembered a metaphor, the idea of using a metaphor to explain climate change was generally appealing. Participant 3 noted that metaphors could be beneficial to non-expert audiences but also when conversing with fellow experts:

Anyway, I absolutely believe firmly to communicate with the non-specialist, heck to communicate with some specialists turning to metaphors is a really valuable way of contextualizing something in a recipients mind, helping them see beyond just the nuts and bolts of the science which might totally confuse them and putting some context into it.

Others also noted how metaphors could help audiences make connections they didn't expect to make and ease audiences into a topic:

Participant 5: I thought you know the metaphor does ring and coming from my training and experience teaching 3 or 4 years before I got into practicing the science that I had studied, it is really important that you educate your audience before you go diving into the details so metaphor comes up often.

While overall thoughts were positive, some experts did initially address either concern about using metaphors or expressed that metaphors should be used with caution. Participant 6 highlighted that:

I've found that analogy works to get people the right idea to get to the right question but there are issues with it and that's why I think it is imperfect.

Participant 10 went a bit further explaining that they are cautious about using metaphors because they do not want to unintentionally mislead someone if the connections between the base and target of the metaphor are not adequately made:

So that is one metaphor we talk about [not using] because it is one metaphor that is misused. It is misleading.

Concerns about metaphors being misleading are legitimate because some metaphors, if not adequately explained and properly used as an explanatory device, the meaning can potentially get lost (Guerra-Ramos, 2011).

Results based on highlighting and valence coding

Overall Reactions to essays

The results of the highlighting and subsequent valence coding allowed an exploration of the sentence and passage reactions per participant and the sample collectively. In calculating the average scores of the passages per expert, positive and negative ratings varied from expert to expert for each essay (Figure 4). Overall the frequency of extreme weather (M = .03, SD = .20), increasing rate of carbon dioxide (M = .11, SD = .22), and the difference between weather and climate (M = -.05, SD = .14) essays were rated slightly positive on average. The enhanced greenhouse effect essay ($M = .03$, $SD = .16$) however was rated slightly negative overall.

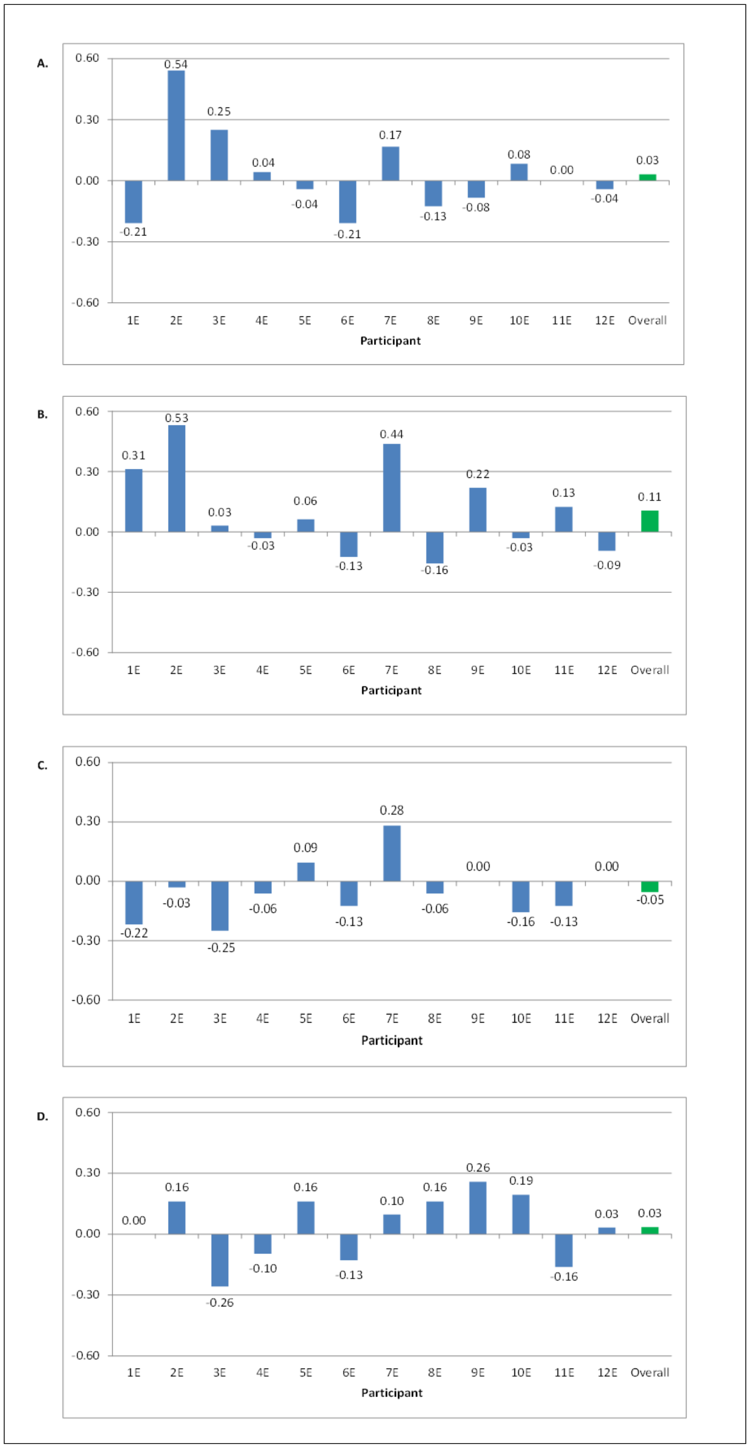

Figure 4. Average essay score of each participant and overall.
Each of the four essays are represented as follows: A) frequency of extreme weather, B) increasing rate of carbon dioxide, C) enhanced greenhouse effect, and D) difference between weather and climate. The average scores by expert (blue), and for all experts (overall - green) were based on sentences being marked as being “liked, accurate, or clear” (+1), “disliked, inaccurate, or unclear” (-1), and not marked at all (0). The closer to 1, the more positive on average the

essay was rated while the closer to -1, the more negative the essay was rated; near 0, the essay had mixed ratings throughout. The blue bars are individual participant average scores, and the green bar on the far right of each graph is the overall average score for the explanatory essay.

The results of the Wilcoxon signed rank test further emphasize the three positive and one negative rating of the essays, and the overall mixed reviews between the experts of each of the four essays. In testing if the median response to an essay was greater than zero, the null hypothesis was accepted. The Wilcoxon signed rank test indicated a positive response to the increasing rate of carbon dioxide (Mdn = .05, $T = 54.5$, $p = .223$); and the difference between weather and climate (Mdn = .06, $T = 42.5$, $p = .394$) essays. Conversely, negative responses to the frequency of extreme weather (Mdn = -.02, $T = 34.5$, $p = .894$), and enhanced greenhouse effect (Mdn = -.06, $T = 14.0$, $p = .168$) essays were found. In all four cases, the null hypothesis that the scores were not significantly different than zero was accepted.

The median average scores of the metaphor and the science components of the essays were also examined to determine if these sections were particularly liked or disliked by the experts. For the reaction scores of the science paragraphs, the median average scores were negative for all four essays: frequency of extreme weather (Mdn = -.01, $T = 30.5$, $p = .759$); increasing rate of carbon dioxide (Mdn = -.03, $T = 36.5$, $p = .844$); enhanced greenhouse effect (Mdn = -.17, $T = 13.5$, $p = .08$); and difference between weather and climate (Mdn = -.01, $T = 30.5$, $p = .821$). Again in all four cases, the null hypothesis that the science average scores were not significantly different than zero was accepted. The more negative ratings of the science paragraphs of the essays is likely due to the fact the participants are content experts, and while objective in their evaluations they were also critiquing the accuracy of the scientific information, terminology and phrasing. More detailed critiques of the scientific accuracy and suggested phrasing and terminology are discussed in the next sub-section of the results.

For the reaction scores of the metaphor paragraphs, the median average scores were positive for all four essays: frequency of extreme weather (Mdn = 0, $T = 15.5$, $p = 0.281$); increasing rate of carbon dioxide (Mdn = .06, $T = 25.5$, $p = .122$); enhanced greenhouse effect (Mdn = .056, $T = 27.0$, $p = .959$); and difference between weather and climate (Mdn = .5, $T = 44.0$, $p = .09$). The null hypothesis that the metaphor average scores was not significantly different than zero was accepted. While the experts were critical of the usage of metaphors to explain the different climate change concepts, the results can be attributed to scientists' objective nature. The metaphors were appealing and generally created a positive discussion about the particular metaphor as well as other topic specific metaphors. These details are discussed further in the next sub-section of the results.

The Wilcoxon signed rank test was also used to determine if there was significant difference between the average scores since the science and metaphor sections were rated differently (negatively and positively, respectively). However, there was no significant difference found between the reactions to the science and metaphor sections of each essay: frequency of extreme weather, $T = 22.4$, $p = .350$; increasing rate of carbon dioxide, $T = 16.5$, $p = .077$; enhanced greenhouse effect, $T = 15.0$, $p = .109$; and difference between weather and climate, $T = 16.5$, $p = .077$. These results demonstrate scientists' mixed feelings about using metaphors as an explanatory tool, and provided constructive criticism of the metaphors, how the science was explained, and the explanatory essays overall. These results are further explored and discussed in the qualitative analysis of the interviews in the following section. Detailed data tables of all Wilcoxon signed rank test results can be found in Appendix A.4 – Wilcoxon Signed Rank Test Result Tables.

Essay analysis sentence by sentence

The results of the highlighting and subsequent valence coding additionally provided a way to focus on sentences or sections of the essays that from an expert perspective required improvements in terms of readability and technical accuracy. Averages for each sentence were calculated to help problematic areas stand out (Figure 5). Reactions by sentences varied throughout the essays, though there are clearly some sentences and sections that required more attention than others. For example, upon examining the enhanced greenhouse effect essay (Figure 5C), many sentences were rated negatively on average; especially the science categorized sentences. Those sentences or sections rated unfavorably were examined closely and edited. Edits were made by referencing statements made regarding the sentence or section of the essay in the interview transcripts and incorporated the feedback received. For example, the third science-categorized sentence in the increasing rate of carbon dioxide essay was reviewed and revised because of its low average rating of -0.75 (Figure 5B). However, this is not to say that the positively rated essay sentences went unchanged when revising the passage; such sentences were simply not scrutinized as heavily and were edited as necessary and to maintain the flow of the essay as other changes were made. From this display of the results, the individual metaphor sentences for the essays were mostly rated positively (greater than zero), on average – with the exception of the enhanced greenhouse effect essay.

Expert views of metaphors used in explanations

The results of the expert interviews are organized by three common themes that emerged during the interviews across all four passages and topics: 1) why or why not metaphors are used to explain climate change concepts; 2) ensuring accuracy of science terminology; and 3) alternative and supplemental techniques for explaining climate change concepts. Implications of these findings are discussed in the next and final section of this chapter.

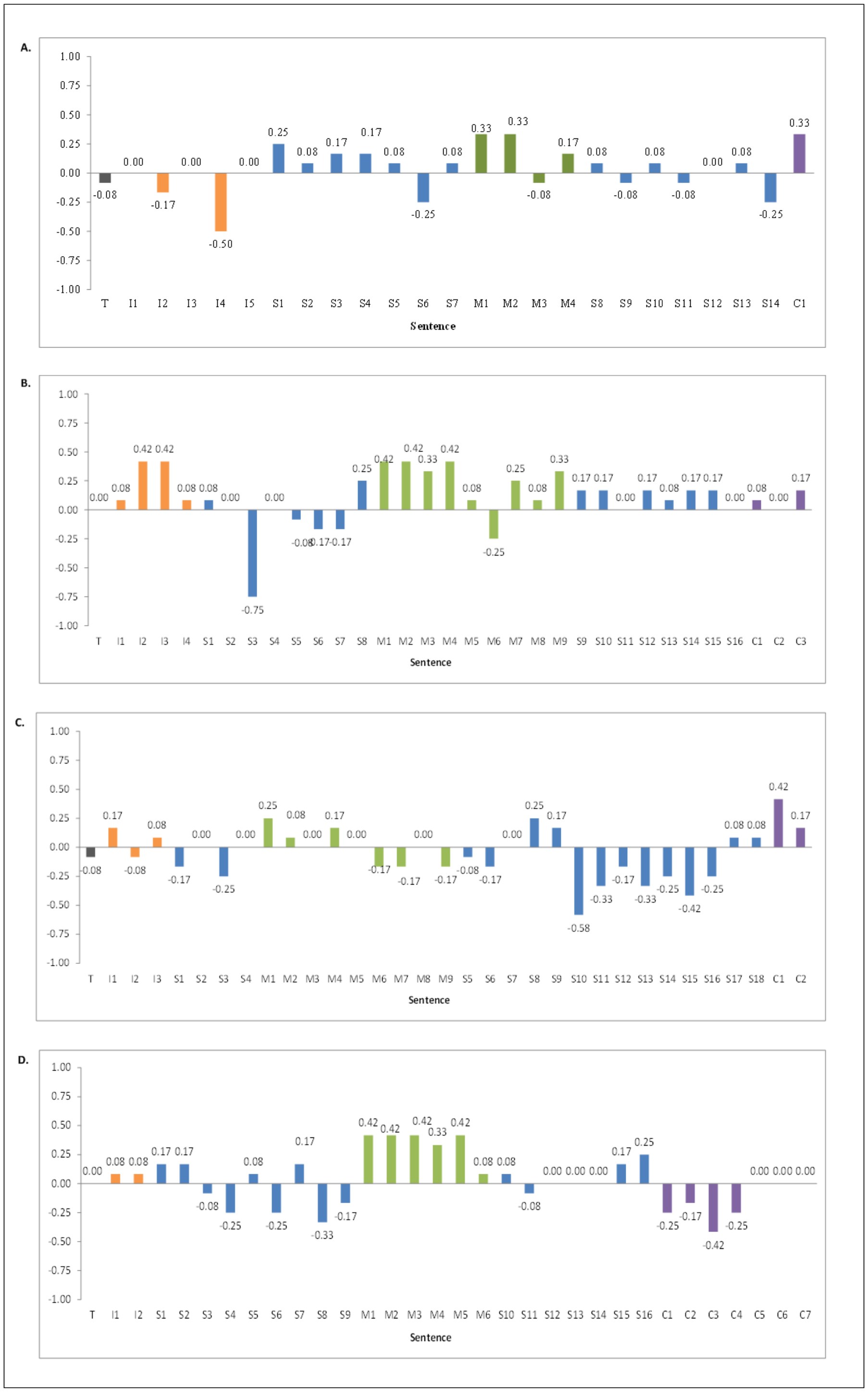

Figure 5. Average sentence scores by explanatory essay.
Each of the four essays are represented as follows: A) frequency of extreme weather, B) increasing rate of carbon dioxide, C) enhanced greenhouse effect, and D) difference between weather and climate. The average scores for each sentence were calculated based on sentences being marked as being “liked, accurate, or clear” (+1), “disliked, inaccurate, or unclear” (-1), and not marked at all (0). The closer to 1, the more positive on average the essay was rated

while the closer to -1, the more negative the essay was rated; near 0, the essay had mixed ratings throughout. Sentence abbreviations and colors correspond to T = title, dark grey; I = introduction, orange; S = science, blue; M = metaphor, green; and C = conclusion, purple.

Why metaphors are used and not used

In reflecting on the four essays and explanatory metaphors, all but one participant expressed that they liked, in general, using or the idea of using metaphors to explain important aspects of climate change. Several participants articulated that they like metaphors, as they are particularly usable explanatory tools. The experts either already use or plan to use metaphors in the future for this reason:

> *Participant 2: [In reference to the frequency of extreme weather metaphor] And I do like, it's an analogy I use myself the baseball analogy with the steroids.*

> *Participant 10: [In reference to the increasing carbon dioxide metaphor] I like that analogy a lot. I might actually use that one.*

Participant 11 even felt that he could take exactly what was written in the increased carbon dioxide essay, and use it in one of his presentations:

> *So yeah I could use this. I could use the last one too. I could use this almost rip and read and feel good about presenting this.*

Half of the participants also commented that they liked metaphors because of the connections that can be made between something that is familiar or relatable to help support the understanding of something that is unfamiliar or complex.

> *Participant 1: [In reference to the difference between weather and climate] I liked it. I really liked this one. People are used to the idea of building statistics for a particular player and for a team and for an entire league.*

Participant 2: [In reference to the frequency of extreme weather metaphor] Metaphors or analogies, I use those all the time. It's easy for people to relate to. I think it's very helpful especially for people who don't have scientific training or background to use analogies and sort of making connections to things they don't understand based on things they do understand or have experience with.

Participant 8: [In reference to the enhanced greenhouse effect] And you're using one that would be familiar to Americans here or people with cars. And people with cars with windows.

It is interesting that the experts interviewed pointed out familiarity of concepts to be an important feature of metaphors. Using a familiar base concept has been shown to be an important factor in improving the comprehension of the target concept (Guerra-Ramos, 2011). If there is a lack of familiarity of the base concept, the effectiveness of the metaphor is reduced (Hoeffler & Herzenstein, 2011), and can lead to misinformation (Gentner & Markman, 1997) and therefore hurt the possibility of improving an individual's understanding of an unfamiliar target concept.

While there were many positive reviews of the metaphors, participants also expressed a level of dislike with particular metaphors. Some aversion to the metaphors was due to the perceived downfalls of the metaphors presented. Several experts acknowledged that metaphors in general are imperfect, and this can be concerning. While the imperfectness of metaphors was mentioned for all four topics, the idea surfaced the most when discussing how to explain the greenhouse effect using the "parked car effect" metaphor for two reasons – 1) the greenhouse effect in and of itself is already a metaphor; and 2) as Participant 4 mentioned:

It’s problematic because the parked car effect as you named it is really a, it’s an open question if this metaphor actually works. It’s not about the greenhouse effect, it’s about suppressed convection. The reason why cars get hotter is suppressed convection.

Such dissimilarity could result in a metaphor “breaking down” and result in a misunderstanding or further confusion. Metaphors have the potential to “breakdown” due to additional factors like: oversimplification, or being overly complicated (Guerra-Ramos, 2011). Some participants also cautioned against over complicating topics that might not need a metaphor – but noted this is also audience dependent. For example, the difference between weather and climate essay added too much detail and buried the point of distinguishing the two concepts:

Participant 3: This thing about the baseball teams, it just gets too much and I start thinking statistics too much... I think it is too much to explain in this baseball, and I think it is more realistic explanation of the difference between weather and climate.

But as Participant 3 noted, “...metaphors are never perfect. They’re just to help illustrate and to help drive home, as if I need to tell you, in a manner that is going to get a point across to an audience.” To avoid metaphors becoming confusing or breaking down, some participants suggested other ways to explain the concepts more clearly and addressed the need to be prepared to acknowledge dissimilarities, like Participant 2:

Another analogy I use which is maybe in some ways more accurate but maybe not as obvious to interpret is the blankets in bed analogy. And the reason that is incorrect, or is less clear is because it is still a flawed analogy. Because when you’re in bed and you’re putting blankets over yourself, you’re the heat source. It’s not the sun is shining and the blankets are warming you and the heat is *getting trapped.... [T]he analogy is if you're in your bed and you have the sheet over you, and you're feeling kind of cold you can pull a blanket up on the bed and you feel warmer. The more blankets you put on the more the heat that it is trapping. Adding CO_2 to the atmosphere is like adding a blanket onto your bed. It's essentially adding a blanket to the climate system. The more CO_2 you have, the thicker the blanket is getting. But again it is a failed analogy and it isn't talking about any sunlight coming in. It's just the thermal part, not the solar radiation part.*

Accuracy of science terminology

As each expert read through the essays, they were keen to point out inaccuracies in scientific terminology, or where clarity was needed in the 'science' paragraphs of the essays. The most problematic sentences when it came to scientific accuracy can be easily seen in Figure 5 where the sentence averages were on average negative. The transcribed interviews were useful in identifying the exact issue with the sentences as well as direct suggestions on how to improve the statement(s). The most common problems with terminology though were the usage of "heat trapping greenhouse gases" and "infrared light."

Throughout all of the essays, the idea of "heat trapping greenhouse gases" was mentioned and more often than not, the inaccuracy of the phrase was discussed:

Participant 1: The problem is the phrase greenhouse gases trapping heat has gotten into our [lexicon]. It is short hand now for the physical origin of climate change. The problem with it is that there is no trapping going on.... The big problem is the word trap. That's not what happens. The physics of climate change is, it's complicated but there is one very simple thing that is going on and that is some the molecules in the atmosphere, some of them, but not all of them have this property that when they are struck by a photon... That greenhouse effect has *nothing to do with trapping heat, it has everything to do with double, well not double, but a very large enhancement of the amount of radiation that is reaching the Earth's surface because as the Earth tries to cool itself off some of the energy it releases doesn't get all the way to space, it gets absorbed and emitted back so the Earth has to absorb it again.*

If the phrase can be avoided, alternatives to "trap" or "trapping" is waylaid or delayed; but Participant 3 said they only substitute in those words if their audience already has a baseline knowledge of climate change. Several experts also indicated that avoiding stating "heat trapping greenhouse gases" is difficult, and also inaccurate, it does get the gist of the idea across to most lay audiences. Participant 1 reluctantly admitted, "If they've heard anything about climate change, that's what they have heard; there are these gases that are trapping heat," so while it is not completely accurate, it is better to use than confuse the audience.

Another term that most experts felt strongly about finding an alternative phrase for was "infrared light."

Participant 4: I think their [National Network for Ocean and Climate Change Interpretation] research would say don't get people into infrared light.

Participant 12: I flagged infrared and visible as something that people might not understand... And I thought a little bit and saw you had visible light and thought a little about how you could say that versus how you can't say long wave and short wave energy because people don't know what that means but there are probably people who have thought about how to communicate these things better than I have... I don't have a solution but just seeing how infrared could be kind of I wonder if people think of infrared they think of I don't know some sort of watching Predator or watching some weird or connotes something sci-fi to them.

The general consensus was that the electromagnetic spectrum is complicated to explain and unfamiliar to most non-scientists, and that the term's best alternative would to simply refer to "energy":

> *Participant 3: Right, it's trapped energy. I wouldn't even say infrared light and heat. I would just say it traps energy.*

Other editorial comments were made including personal preference of the order or structure of sentences. All suggestions on improving the accuracy of scientific terminology and clarity were seriously considered when revising the essays for the second study involving interviews with non-experts.

Other explanatory techniques

In discussing explanatory metaphors, it seemed very natural for the experts to discuss alternative or complementary explanatory techniques leveraged when talking to lay audiences about climate change. Four participants though also admitted that they often rely on sharing hard data and facts with their audiences. However, while providing audiences with facts, they recognize that pairing facts with visuals, examples, or other and more interactive components are helpful. For example, Participant 5 said that they often go straight to the data first, but provides local examples that pair well and accurately with the data: "So I tend to head to the data.... So I show them the data locally so that people remember it and I bank on their recollection of history."

In addition to facts and examples, experts said they have used visual aids (pictures, graphs, graphics, etc.) to explain climate change to lay audiences. Participant 10 particularly likes to use, "a [really] nice graph that was produced by the Bloomberg group where they show these natural carbon variations for example the ice ages and solar activity cycle” to explain the increasing rate of carbon dioxide and leads into also talking about the greenhouse effect. Participant 9 also indicated that metaphors, particularly the carbon dioxide bathtub, are very visual. More specifically she has seen an interactive graphic and was imagining “drawing or [having] an interactive [graphic] where you can click on the tub and have little words pop out” as someone talks about the increasing carbon dioxide and global temperatures.

The experts interviewed in this study expressed in one way or another that simply providing facts to lay audiences – following the deficit model – to guide people in understanding climate change better is not sufficient. Thus employing the previously mentioned alternatives in talking to and connecting with lay audiences were paired with the disseminating of facts. As they have acknowledged this, it has opened them up to the possibility of using explanatory metaphors. Using explanatory metaphors can help fill in gaps between the facts and figures shared in the discourse between experts and non-experts (McGlone, 2007; Volmert, 2014) and serve to deepen the understanding about a topic.

Other important considerations

As climate scientists, the participants in this study have built up their credibility throughout their careers through education, conducting and publishing research, speaking at conferences, and by service to their field. This credibility translates into expertise from the public’s perspective and is perhaps disproportionately relied upon by scientists when communicating to the public. Experts addressed their concern about maintaining credibility when talking about climate change both in general, and when using explanatory metaphors. They do not want to tarnish their credibility with lay audiences, as expressed by Participant 2, "I'm always very careful not to misspeak" and was echoed by Participant 6:

> *I'm very careful about that. I'm very sensitive to it because I try to convince audiences that I have no agenda and I don't.*

The concern about using metaphors to communicate about climate change and the impact on credibility can be traced back to the imperfections of metaphors, as Participant 5 stated, "I haven't used metaphors much because they are imperfect and something could go wrong at the receiving end, maybe diminish my expertise."

Being concerned about maintaining one's credibility with a lay audience when presenting about climate change is not an uncommon position. However it is important to note that when a speaker uses a metaphor, they are often identified by an audience as a more credible source of information (McCroskey & Combs, 1969) in addition to developing a connection between speaker and listener (Gibbs, 1987).

Conclusion

Overall, the experts who participated in this study were enthusiastic and reacted positively to the essays and metaphors. The experts did say that they sometimes use metaphors when talking to lay audiences about climate change. However, initially many found it challenging to think of or articulate what metaphors they had used or heard used in the past. After reading the essays though, they were reminded of either using or hearing the metaphor, or other metaphors explaining the concept before (See appendix A.3 – List of expert-generated metaphors from interviews by topic). The participants were objective in their critiques of both the science and metaphor components, suggesting how to edit terminology or phrases to be more accurate and clearer. Some of the metaphors were liked more than others, but the participants were always able to explain why some were favored while others were not, and frequently provided advice on how to improve the current explanatory metaphor, or described an alternative that they felt was more appropriate. As for the science components of the essays, some experts were particular about phrasing and order of information. Both phrases, "heat trapping greenhouse gases" and "infrared light," were heavily scrutinized. However, experts provided alternative words or phrases to improve the clarity of the essays that still communicate the same idea but more accurately. Metaphors were also viewed as being particularly effective or useful if the base concept was familiar or relatable to their audience, thus allowing individuals to make appropriate connections to the less familiar and new climate change concept.

The feedback received in the expert interviews was particularly valuable because experts are the users – or potential users – of metaphors as a communication technique, and it is important to know from their perspective if they find metaphors to be useful in presenting climate change information to lay audiences. Thoughtful critiques additionally addressed the appropriateness of the metaphors and contributed to the understanding of the practicality of using metaphors. The commentary regarding the accuracy of the science was also integral as it eliminated incorrect or misleading information in the stimulus materials. In revising the stimulus materials, all of the previously mentioned points were considered, though it is not enough to know what technical experts believe or feel about a particular communication technique or what lay audiences need to know

(Bostrom, Morgan, Fischhoff, & Read, 1994; Fischhoff, Slovic, & Lichtenstein, 1982; National Research Council Committee on Risk Perception and Communication, 1989). Hence in the next chapter, non-experts are interviewed and they in turn reviewed the revised essays.

CHAPTER 4. STUDY 2 – NON-EXPERT REACTIONS TO CLIMATE CHANGE EXPLANATORY METAPHORS

4.1 Introduction

Elucidating current conceptions, understanding, and knowledge of climate change is helpful in designing informative and persuasive messages about climate change science, policy, and action. Knowing that Americans do not have fully coherent or accurate ideas about climate change (Leiserowitz et al., 2010), it is helpful to address their current mental models before explaining alternative models (Rowan, 2003). It is also important, though, to determine if people do not have strong mental models of climate change and thus introduce clear and simple explanations by providing a model through which to understand the complexities of climate change and avoid common misconceptions. Identifying what people incorrectly perceive, and have little knowledge about, can help guide explanatory message development, which is relatable and meaningful for climate change.

This chapter addresses how the knowledge of non-expert mental models can be used in developing explanatory metaphors and enhance the understanding and persuasive power of climate change messages. It also details the reactions of non-experts of climate change to four explanatory passages using four different metaphors each tailored to a specific climate science topic. The referenced passages had been previously reviewed by experts and subsequently edited. Thus this study continues to follow the next steps suggested by Morgan and colleagues (2002) in developing effective messages for non-experts: 3) examine non-expert mental models, and 4) compare expert and non-expert mental models. By conducting qualitative research (one-on-one interviews), a deeper understanding of an individual's knowledge base (or lack of) can be better obtained (Zaltman, 2003), and explanations that participants articulate provides insight into where misconceptions arise.

Using relatable language to enhance understanding and persuasiveness

By taking an accommodation theory perspective, it may be possible to increase persuasive power if the language used to articulate climate change information conveys the communicators' understanding of the audience's position. If an audience's views and/or understanding of climate change, for example, is better understood, a message aimed to enhance or correct the previous understanding can be constructed. In other words, the structure, tone, style, and language can and should be accommodated for what is already known or not known about the audience's knowledge and attitudes. This idea has been identified as convergence, a strategy where communication behavior becomes more similar to an audience that disseminated information is trying to reach (Gallois, Ogay, & Giles, 2005). However, much information regarding climate change is rather technical and full of jargon. Sharing climate change information in such a manner is more in line with the strategy of divergence and in this case the scientific information remains at or close to its original style regardless of the audience it is trying to reach. This is problematic if the end goal is to increase non-scientific audiences' awareness and motivate them to take action on climate change. Hence accommodating literal, scientific language into more easily digestible and relatable formats (i.e. converging), such as in using a metaphor, is a possible winning strategy for improving understanding, and can be more persuasive.

Moreover, the relatability of information created by metaphors allow for mental models to be molded and created to link abstract climate science to more intuitive knowledge. For example, the complex climate science concept of more frequent intense storms has been compared to loaded dice. People are familiar with the concept that loaded dice – dice that have been altered with small weights – make rare outcomes more common; similarly, the atmosphere has been altered or loaded, with additional greenhouse gases, making rare intense storms more frequent. Metaphors also help make connections through referencing memory (Gentner, Holyoak, & Kokinov, 2001) which can include facts, feelings, and experiences. Metaphors can elicit a range of feelings (Lakoff, 1993). Depending on what that feeling projected and created by the metaphor, decisions and actions are either positively or negatively impacted, which is apparent under risk and uncertainty (Loewenstein, Weber, Hsee, & Welch, 2001; P. Slovic, Finucane, Peters, & MacGregor, 2004).

Objectives

The primary motivation for this research was to understand how lay audiences currently make sense of climate change and how they process climate change information explained through metaphors. Inspiration for this study also stemmed from the fact that the public largely views climate scientists as trusted and credible sources on climate change (Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Howe, 2012; Leiserowitz, Maibach, Roser-Renouf, Smith, & Hmielowski, 2011) and thus metaphors were collected and reviewed directly by climate science experts and reputable sources in preparation for this investigation. Moreover, qualitative interviews can be used to explore, at least in preliminary terms, the efficacy of particular researcher-developed metaphors, and these findings can then inform future message testing research, conducted via quantitative surveys.

The intention of this research was to specifically explore and shed light on how individuals construct their perspective on the issue of climate change and process explanatory passages that use metaphors. The main goals of interviews was for participants to: 1) discuss how they make sense of climate change and related concepts "while imposing as little as possible of other people's ideas, perspectives, and terminology" (Morgan, Fischhoff, Bostrom, & Atman, 2002, p. 63); and 2) record reactions of participants to explanatory passages using metaphors to more clearly understand non-expert mental models. These interviews provide insight towards improving the original metaphors of the pilot study and the expert interviews by altering the language and incorporating non-expert mental models, and perhaps even a metaphor that resonates better. Specifically, this study was focused on answering:

> ***RQ3:*** *How do lay audiences currently make sense of climate change and related concepts?*
> ***RQ4:*** *How do lay audiences react and process climate change information when presented with explanatory metaphors?*

4.2 Methods

Sample

This study recruited 30 adult participants at two coffee shops, one in Virginia (10) and one in Delaware (20), between April 7 and April 17, 2016. The sample size is theoretically sufficient, as Morgan et al. (2002) affirm that after about 20 interviews the number of unique concepts that are uncovered reaches a saturation point, and begins to level off as few new concepts emerge. All participants were assigned a number to maintain anonymity and identified as non-experts of climate change science. Of the individuals interviewed, 17 were male and 13 were female.

Prior to the interview, individuals were asked to complete a three-item questionnaire for screening purposes: two items combined to measure climate change belief certainty; and one item included six descriptive options, each representing a Global Warming's Six Americas segment, thus each participant self-selected which segment they felt described their beliefs and concerns about climate change (see Appendix B.1 – Study 2 Screening Questionnaire for Non-Expert Interviews). The single item approximating the Global Warming's Six Americas audience segment has not been shown to be a valid indicator of an individual's Six Americas status. The purpose of the screener was to provide an initial baseline of participant views of climate change, and to provide an approximate characterization of a participant's audience segmentation status within the Global Warming's Six Americas prior to participating in the study. While there was no set quota, the screener was used in attempt to adequately represent each segment in the sample as best as possible (e.g. a sample of only Alarmed and Concerned individuals would not be sufficiently representative). Therefore some individuals who were interested in participating were turned away after completing the screener in an attempt to achieve such representation. The responses collected from the screener were not used in any analysis for this study. More than two-thirds of the participants could be characterized as Alarmed, Concerned, or Cautious (Figure 6), which is not surprising as about two-thirds of the American population falls into those audience segments based on a nationally representative sample (Leiserowitz et al., 2015). About 87% of the participants were at least somewhat sure that global warming is happening (Figure 7). In comparison to the American population, the sample interviewed was much more convinced that climate change is happening; on average, about 40% are extremely or very sure climate change is happening. Each participant received and signed a written consent form prior to participating in the interview, according to the approved Institutional Review Board (IRB) procedures at George Mason University. This included notification that upon completion of the interview participants would receive $15.00 in appreciation for their time.

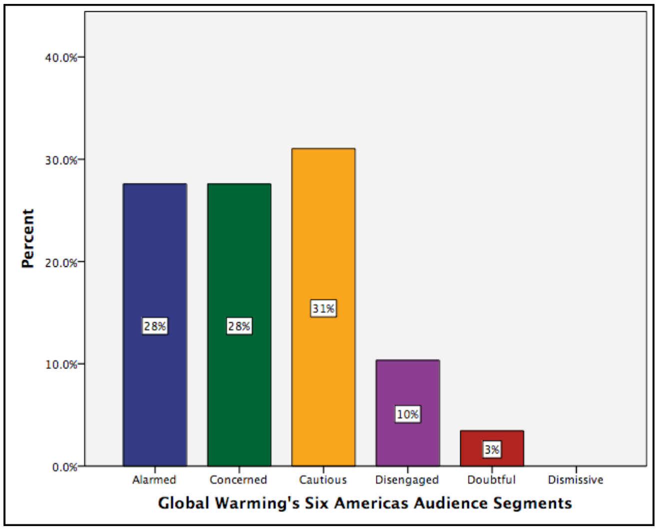

Figure 6. Non-expert participants Global Warming's Six Americas audience segmentation.
This figure illustrates which audience segments interview participants were categorized based on responses collected from pre-interview screener questionnaire.

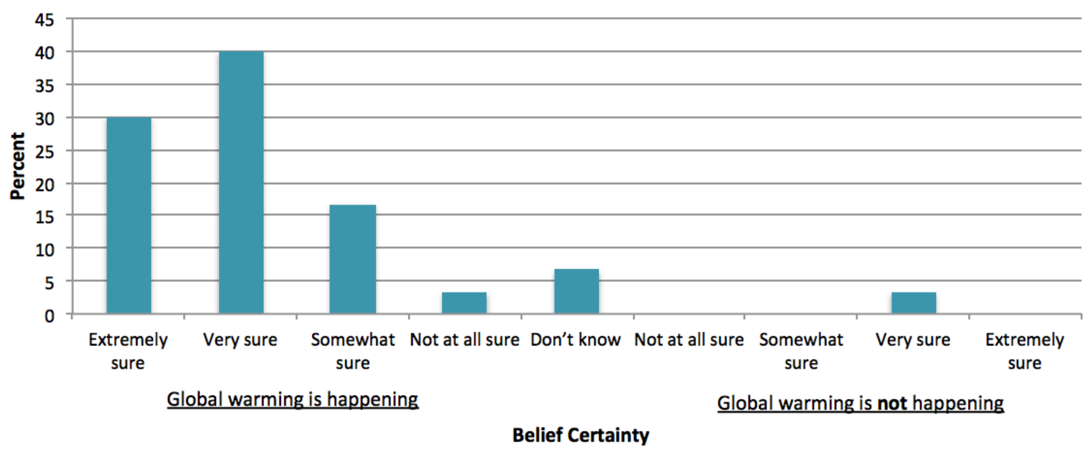

Figure 7. Non-expert belief certainty.
Belief certainty was calculated using questions 1, 2A, and 2B on the pre-interview screener questionnaire. This figure illustrates the distribution of belief certainty for the sample.

Interview design and procedure

The interviews were semi-structured, and designed to capture the level of understanding each individual has of climate change, and solicit feedback on four explanatory passages in which each passage used a metaphor to explain a climate change concept. The interviews employed an in-depth interview strategy, similar to a mental model interview strategy (Morgan et al., 2002), which is similar to the metaphor-elicitation process described by Zaltman (2003). This helped to facilitate the participants' articulation of thoughts, feelings, and behaviors in relation to climate change, and the related concepts addressed in the four essays. The interviews took an average of 39 minutes (ranging from 25 to 60 minutes). Interviews were divided into three parts: introductory questions about climate change concepts; reading and discussing each of the four short essays (core of the interview); and concluded with asking participants to explain what climate change is and any other final thoughts or suggestions for further consideration (see Appendix B.2 – Study 2 Interview Guide).

The introductory questions were broad and open-ended (e.g. "Tell me what you know about 'X'?), with a series of follow-up questions (e.g. "What more can you tell me about 'Y'?) to dig deeper into what and how they understand a concept. The central portion of the interview focused on reviewing the four short explanatory essays, and discussing what was liked and disliked, as well as clear and unclear, in order to get a sense of how people process such explanatory passages. Prior to reading the first essay, participants were provided with a green highlighter and red pen. Each participant was asked to use the green highlighter to mark what he or she found to be especially clear or helpful; and to use the red pen to underline what he or she found to be especially confusing or unhelpful. These instructions were also provided at the top of each page: "Read the following passage. Highlight in green what you find especially clear or helpful, and underline in red what you find especially confusing or unhelpful." After reading each essay, participants were asked what their overall thoughts were about the short explanation to get a general, broader reaction to the essay before discussing specifically about what and why certain parts were highlighted and underlined. The interview then turned to discuss what sentences, phrases and words were highlighted in green, and why. This was followed-up by a similar discussion about the items underlined in red. After addressing the highlights and underlines, participants were asked to briefly articulate how they might explain the topic they just read about to someone else (i.e. a family member, friend, an eighth grader). The concluding question after each essay, and the final interview question allowed for the opportunity to examine what was understood about climate change directly after reading about climate change, and whether the explanatory metaphors would potentially be used or re-articulated by non-experts.

Each of the four essays explained one climate change concept, and incorporated a metaphor into the explanation tailored to the topic (see Appendix B.3 – Study 2 Stimulus Materials for Non-Expert Review). The four topics were: 1) the frequency of extreme weather events; 2) the rate at which carbon dioxide is increasing; 3) the enhanced greenhouse effect; and 4) the difference between weather and climate. Respectively, the metaphors were: 1) the frequency of homeruns hit by a baseball player on steroids; 2) the rate at which water enters and exits a bathtub; 3) the effect on a parked car in the sun during the summer; and 4) baseball statistics – the outcome of a baseball player up at bat and his batting average. The essays were on one page (8 ½ by 11) each, and were between 480 to 550 words, taking participants on average three and a half minutes to read each passage (reading times ranged from 2.5 to 9 minutes). These essays had been previously revised based on the expert interviews presented and discussed in the previous chapter. Each essay consisted of a title phrased as a question, a short introductory paragraph, a short metaphorical explanation, a science-based explanation, and concluded with a summary paragraph.

Coding and analysis approach

All 30 interviews were audio-recorded and transcribed verbatim. Following a similar procedure used by Maibach et al. (2010), sentences, phrases or words highlighted in green were assigned a score of +1. The green highlighting indicated the sentence was clear or helpful to the participant's understanding, or generally liked. Conversely, anything underlined in red was assigned a score of -1, indicating the sentence was unclear, unhelpful, or generally disliked. If nothing was highlighted or underlined, or a combination occurred in one sentence, these sentences received a score of 0. If only a phrase or word was highlighted or underlined, the phrase or word was recorded in a spreadsheet. Average scores were calculated for each essay by non-expert, each essay overall, the metaphor paragraph, and the cumulative science paragraphs. Sentence average scores in each essay were also calculated. The Wilcoxon signed rank test was used to evaluate if the median response score of the essay, metaphor paragraph, and science paragraphs was greater than zero, or in other words a positive reaction, for the full sample per topic. The Wilcoxon signed rank test was appropriate here due to the small sample sizes and non-normal distributions of the data.

Additional analyses included the coding of the interview transcripts to more fully describe and understand the reactions to each of the four essays. Coding was primarily data-driven and used an inductive coding process in the tradition of grounded theory (Charmaz, 2006). Several theoretical categories emerged through constant comparison of the discrete segments of participant discourse, and through additional analyses, relationships between key categories, especially between those pre- and post- metaphor exposure, surfaced (Charmaz, 2006). For each interview, open coding was completed, followed by axial coding to refine categories and to determine where categories interconnect. QDA Miner, a qualitative data analysis software package was used during the coding process to annotate, retrieve, and analyze data collected.

4.3 Findings and Discussion

Many of the non-expert participants were interested but anxious about participating, but as the interview progressed they became more relaxed, engaged and open in the interview. The analyses of the results are reported in three parts. The first portion of the results includes a summary of participants' baseline awareness and knowledge of climate change. Introductory questions were asked which allowed for individuals to share what first comes to mind when they hear something about climate change, and instigated a brief discussion about what – if anything – they knew about the four focal concepts they would encounter in the explanatory essays.

Quantitative and qualitative analyses were also applied to the more specific reactions captured in the interviews to each of the four essays read and subsequently discussed. The reactions to the four essays were observed quantitatively in the same fashion that observations were made of the expert reactions: through scoring the sentences based on the highlights and underlines made by each non-expert. Again, this analysis approach provides a snapshot of the instant reactions participants had to the essays while the qualitative analysis delves into much more detail of how non-experts responded, interpreted, and processed the explanatory passages involving metaphors. A qualitative analysis of statements made during the interviews was thematically coded to better understand the positive, as well as negative, reactions to the essays. Additionally, explanations participants provided after reading and discussing the essays were also examined as a way to understand what the non-experts grasped from the essay and what or how they may share what they learned.

Baseline climate change awareness and knowledge

All but one of the participants positively affirmed they had heard and knew something about climate change. The most common idea that came to mind first when participants heard about "climate change" was the melting of ice caps or glaciers and the polar regions of the globe – something that is far away from where they live. Other common topics that participants first thought of included impacts and causes climate change – sea level rise, changes in weather patterns, polar bears, natural and human caused carbon dioxide emissions, deforestation, and burning of fossil fuels. Several participants also expressed how climate change makes them feel, using adjectives such as worried, scared, or anxious when talking about the issue. As Participant 4 articulated: "Honestly [I feel] a bit scared for my future. Personally it's the thing that scares me the most."

When initially asked to explain the four more specific climate change related concepts, the majority of participants were hesitant to answer. In some cases participants simply stated they did not know much about a topic or topics, had not heard something about a topic(s), or were not confident enough to repeat what they thought they knew or heard. However, with some encouragement some participants made an attempt to explain; if they really did not feel comfortable trying to explain a concept, participants were not forced to provide an answer and the interview continued. Several explained they had learned most of what they know about climate change through news outlets. This in particular is not surprising as it has been found that the general public receives most of its knowledge about science and scientific issues from the media (Boykoff & Boykoff, 2007; Nelkin, 1995; Wilson, 1995).

There were several instances where participants appeared to have the gist of a concept. The greenhouse effect and increasing carbon dioxide in the atmosphere were the first set of topics to be discussed. In initially discussing the greenhouse effect, 22 of the participants said they had heard of the concept, with many following up quickly and without a prompt saying they didn't know much about it or couldn't really explain it. However with some encouragement and additional probing questions, some participants tried articulating an explanation. Most knew about carbon dioxide, as well as other greenhouse gases. Sources of carbon dioxide were also often mentioned, including cars and energy production, and led into discussing that carbon dioxide as a greenhouse gas is causing the Earth to heat up. Participant 18 explained that when "...the heat comes in and the CO_2 gases and other things that are in the atmosphere trap that heat and it's just a sort of spirals" and that is how carbon dioxide and the greenhouse effect plays a role in climate change. One particular participant concisely explained how carbon dioxide accumulating in the atmosphere influences the greenhouse effect and climate change rather well comparatively:

> *Participant 24: The greenhouse effect is when excess carbon dioxide accumulates in the atmosphere which tends to reflect the heat back to the earth's surface or keep the heat from evaporating but I don't know if evaporate is the right word, but diffuse out into the atmosphere. It tends to keep it in like a roof on a house.*

As these topics are challenging to explain clearly and accurately for non-experts, they did make a best effort and in doing so demonstrated how different concepts were related and even sometimes segued from one topic to the next without prompting. For example, Participant 19 indicated that the increase in carbon dioxide plays a role in the greenhouse effect, and in turn influences the weather in some way:

> *The greenhouse effect is when things get really warm and the heat stays compressed like in a greenhouse type thing. I assume that has to do something related with the weather. So the weather must be part of it some how.*

The last set of topics in the first part of the interview included the relationship between weather and climate, and how climate change is influencing the weather. Again, approximately half abstained from providing any explanation, while the other half of participants tried to provide their best explanation. In distinguishing weather and climate, several participants provided concise definitions that incorporated the spatial and temporal components of the concepts:

Participant 18: Weather is local, climate is global.

Participant 24: I mean weather is like a snapshot and climate is the conditions over long periods, as I understand it.

Participant 28: Weather is the day-to-day change in the environment and climate is patterned long-term changes in the environment.

While Participant 26 did not define weather and climate, they explained that extreme weather was becoming more common:

There are more extreme storms that have occurred. Once again I think people are postulating that that is the result of climate change. It's occurring. The thermal warming of the atmosphere is creating much more significant droughts, it's causing droughts in areas where there weren't before.

Other participants who did not define nor provide an explanation distinguishing weather and climate also alternatively acknowledged they had noticed or experienced changes in weather patterns or extreme weather, either directly or indirectly:

Participant 3: [I traveled to] Bolivia this summer actually for a month so my family, my mom's side of the family is from there and there was a lot of differences in climate change from this time then other times that I have been there and I've always gone in the summer time so it should be relatively similar each time... It was really interesting to me and it was the first time it had snowed in a while ... So a lot of people were really surprised that lived there locally and were locals in La Paz and there was a lot more snow than there usually is.

Participant 15: I think about the, you know I'm 64 years old, and when I was growing up, so I live in the house that my grandfather built, so I grew up in a *house my father grew up in and I grew up in ... There's been a difference in the climate and I remember because it is the same location.*

Sometimes though the explanations incorporated a misconception. For example Participant 12, in attempting to explain how the greenhouse effect plays a role in climate change stated: “It's just that we're [the greenhouse effect is] holding [in] the heat and not letting it dissipate so to speak of. So again this is the [hole] from what I gather.” Five other participants mentioned that greenhouse gases are causing the ozone layer to deteriorate as well. Relating the ozone layer depletion to climate change when asked about the greenhouse effect’s relationship to climate change is a relatively common observed misconception (Bostrom et al., 1994; Leiserowitz & Smith, 2010; Niebert & Gropengiesser, 2012; Seacrest, Kuzelka, & Leonard, 2000). Additionally, of the 30 participants only two equated weather and climate, or in other words they explicitly said there is no difference between the two concepts. This widespread erroneous equation of weather and climate has been observed in lay audiences, and is persistent because when notable (extreme) weather events occur, a discussion and questions about climate change arise (Bostrom et al., 1994; Reynolds, Bostrom, Read, & Morgan, 2010; Elke U. Weber & Stern, 2011).

There were also a few participants who expressed concern, or skepticism, or uncertainty about whether climate change is happening, and emphasized that when they think of climate change they are very skeptical. Participant 7 specifically said that he “first definitely thinks [of] Al Gore” and went on to point to a recent campaign event of Ted Cruz’s where someone asked him about climate change and Cruz’s response further supported the participant's personal skepticism about climate change. The themes of controversy and skepticism were distinctly persistent throughout the interview for two participants in particular, and appeared sporadically for several other participants.

Overall in the introductory portion of the interview, individuals were often hesitant or abstained from providing an explanation despite acknowledging they were aware of the concepts and asking a few additional guiding questions. After some encouragement though, several participants did try to explain what they knew or had heard others say about the different climate change concepts. Although they often indicated that the topics were complicated and that they knew only a little about each. In these explanations a couple misconceptions surfaced. However, explanations and examples provided demonstrated that the gist of the concepts were understood.

Results of highlighting and valence coding

Overall reactions to essays

Following the same procedures as in the expert interview study (Ch. 3), again the results of highlighting and underlining, as well as the subsequent valence coding allowed for an exploration of sentence and passage reactions per non-expert participant and the sample collectively. The average scores of the passages per non-expert were mostly positive, though with a few participants rating some passages negatively (Figure 8). Overall the frequency of extreme weather (M = .14, SD = .33), increasing rate of carbon dioxide (M = .25, SD = .31), enhanced greenhouse effect (M = .27, SD = .30), and the difference between weather and climate (M = .09, SD = .24) essays were all rated positively on average.

The Wilcoxon signed rank test was also used to assess the understanding and clarity of the passages from the non-experts point of view. Performing this statistical analysis further emphasized the overall positive ratings of the four essays. The null hypothesis that the median response to an essay was not significantly different from ero was rejected. The Wilcoxon signed rank test indicated significant and positive responses to all four essays: frequency of extreme weather, Mdn = .12, $T = 312.5$, $p = .012$; increasing rate of carbon dioxide, Mdn = .17, $T = 367.5$, $p = .000$; enhanced greenhouse effect, Mdn = .23, $T = 339.0$, $p = .000$; and difference between weather and climate, Mdn = .16, $T = 341.5$, $p = .000$. The fact that the overall reactions to the essays, based on the highlighting and underlining, were positive is a promising outcome. Studies have shown that if individuals positively evaluate a source or messenger (i.e. likeable, attractive, or expertise), they understand better, learn more, and their attitudes towards a topic are affected (Anderson et al., 2013; O'Keefe, 2002; Petty, 1997). While the essays were not attached to a specific source, they were evaluated positively and could potentially have the same positive effects of improved understanding and attitude change towards the topics. The overall positive reactions are further discussed in detail and indicate more specifically what participants liked (and didn't like) about each essay.

The median average scores of the metaphor and the science components of the essays were also examined to determine if these sections were particularly liked or disliked by the non-experts. For the reaction scores of the science paragraphs, the median average scores were positive for all four essays, but significantly higher than zero for only three essays: frequency of extreme weather (Mdn = .09, $T = 261.0$, $p = .008$);

increasing rate of carbon dioxide (Mdn = .13, $T = 295.5$, $p = .002$); and difference between weather and climate (Mdn = .23, $T = 297.5$, $p = .000$). For these three essays, the null hypothesis was rejected. However, for the enhanced greenhouse effect essay, the null hypothesis was accepted (Mdn = .08, $T = 226.5$, $p = .084$). For the reaction scores of the metaphor paragraphs, the median average scores were also positive for all four essays. However, only two of the four topics were positive and statistically significantly higher than zero, and the null hypothesis was rejected: increasing rate of carbon dioxide (Mdn = .13, $T = 270.0$, $p = .001$); and enhanced greenhouse effect (Mdn = .19, $T = 293.0$, $p = .073$). For the other two essays, the frequency of extreme weather (Mdn = .14, $T = 189.0$, $p = .116$) and the difference between weather and climate (Mdn = .13, $T = 181.5$, $p = .073$), the null hypothesis was accepted. Similarly, these positive reactions to the more technical science sections as well as the metaphors of the essays are promising. In thinking about and comparing these results to the expert reviews of the essays, the non-experts were less critical and more subjective in their reactions and feedback. However, this was not unexpected as the non-experts were specifically chosen because they are not content experts and therefore were not critiquing the essays from the same perspective as the experts. The components that were particularly clear or liked are also discussed later in more detail, as well as why the essays and different sentences and sections were rated positively or negatively.

The Wilcoxon signed rank test was also used to assess whether there was a significant difference between the way participants reacted to the science and the metaphor components of the essays. As indicated previously, both the average essay scores and the median average essay scores were positive (higher than zero) – some statistically significantly higher than zero. However, there was no significant difference found between the reactions to the science and metaphor sections of three of the four essays: frequency of extreme weather, $T = 197.0$, $p = .847$; increasing rate of carbon dioxide, $T = 223.5$, $p = .406$; and difference between weather and climate, $T = 237.0$, $p = .249$. For these three essays, the null hypothesis that there was no significant difference found between the reactions of the science and metaphor components was accepted. When comparing the median average scores of the metaphor and science sections for the enhanced greenhouse effect essay, the metaphor section was statistically significantly higher than the science section, $T = 95.0$, $p = .041$. This finding was interesting as all the median average scores were higher for the metaphor paragraph than the science paragraphs, though only one of the tests was statistically significantly higher. Detailed data tables of all Wilcoxon signed rank test results can be found in Appendix B.4 – Wilcoxon Signed Rank Test Result Tables.

These results demonstrate that interview participants viewed the essays positively overall. When examining the average scores of the metaphor sections, it is interesting that only two of the four essays were viewed positively, while three of the science sections were rated positively. Since the metaphor was presented prior to the science, perhaps this increased the science average scores, thus there was no significant difference between the sections, or in the one case the science was scored significantly more positive than the metaphor. Sopory and Dillard (2002) in completing a meta-analysis of papers that examined the persuasive effects of metaphors concluded that when presenting metaphors the position of the metaphor in a passage matters. More specifically, if the metaphor is presented early, the reader or listener tends to be more persuaded by the message and remember the information learned (Mayer & Bromage, 1980; Sopory & Dillard, 2002). These results though only skim the surface of the reactions to the explanatory essays using metaphors for the four different climate change topics. The more detailed feedback on each essay, as well as metaphor and science components is discussed in the following section which help to explain these findings further.

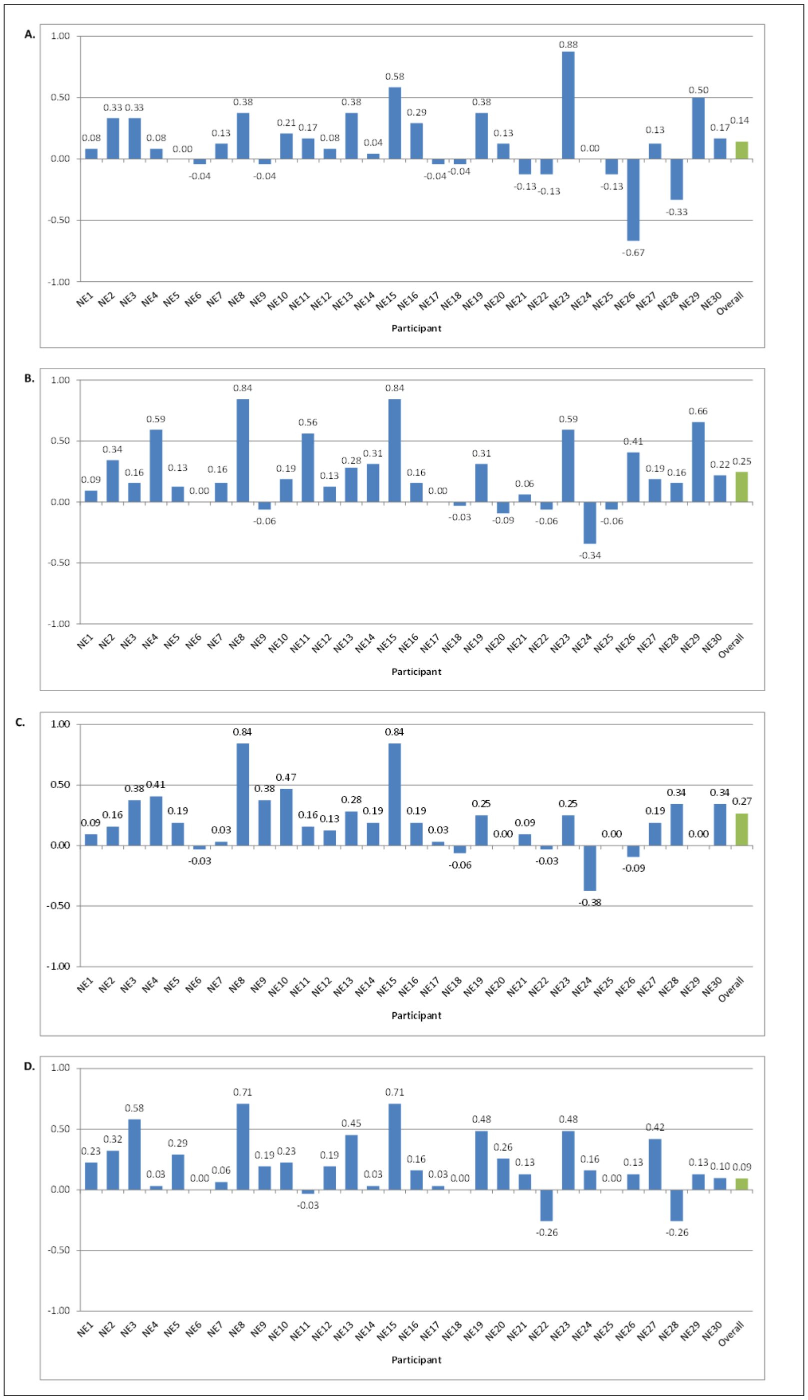

Figure 8. Average essay score of each participant (NE = non-expert) and overall sample.
Each of the four essays are represented as follows: A) frequency of extreme weather, B) increasing rate of carbon dioxide, C) enhanced greenhouse effect, and D) difference between weather and climate. The average scores by non-expert (blue), and for all non-experts (overall - green) were based on sentences being marked as being “liked, accurate, or clear” (+1), “disliked, inaccurate, or unclear” (-1), and not marked at all (0). The closer to 1, the more positive on average the essay was rated while the closer to -1, the more negative the essay was rated; near 0, the essay had mixed

ratings throughout. The blue bars are individual participant average scores, and the green bar on the far right of each graph is the overall average score for the explanatory essay.

Essay analysis sentence by sentence

The highlighting and underlining executed by each participant provided an additional way to assess where sentences or sections of the passages were troublesome and required improvements in clarity and readability. Averages for each sentence were calculated to place an emphasis on any problematic areas (Figure 9). Reactions by sentences varied throughout the essays, though there are clearly some sentences and sections that required more thought-out explanations to increase the clarity or helpfulness of the sentence or section. For example, upon examining the enhanced greenhouse effect essay (Figure 9C), one particular sentence (S7) stands out as it was rated negatively on average. Due to the overwhelming positive scores for each sentence, attention was drawn to sentence scores that simply were visibly much lower than other sentence, albeit still positive. Those sentences or sections rated less favorably were also examined closely and edited. Referencing statements made regarding the sentence or section of the essay in the interview transcripts, the feedback received was incorporated into the essays during editing. For example, in Figure 9D, sentences M1 through M8 (the metaphor section) has relatively low average scores. The baseball statistics metaphor was reviewed and replaced with a different metaphor to examine in a follow-up study. Similarly the baseball player on steroids metaphor also appears to be rated positively, but lower than other metaphors as well as lower than other sections of the frequency of extreme weather events essay (Figure 9A). The baseball player on steroids metaphor was not replaced because it is a commonly used metaphor by experts, and instead revisions were made to improve the flow and clarity of the paragraph. The more positively rated essay sentences did not necessarily go unchanged when revising the passage. Such sentences were simply not specifically targeted and were edited as necessary to maintain the flow of the essay as other changes were made. As Figure 9 shows, the metaphoric sentences were rated positively (greater than zero), on average.

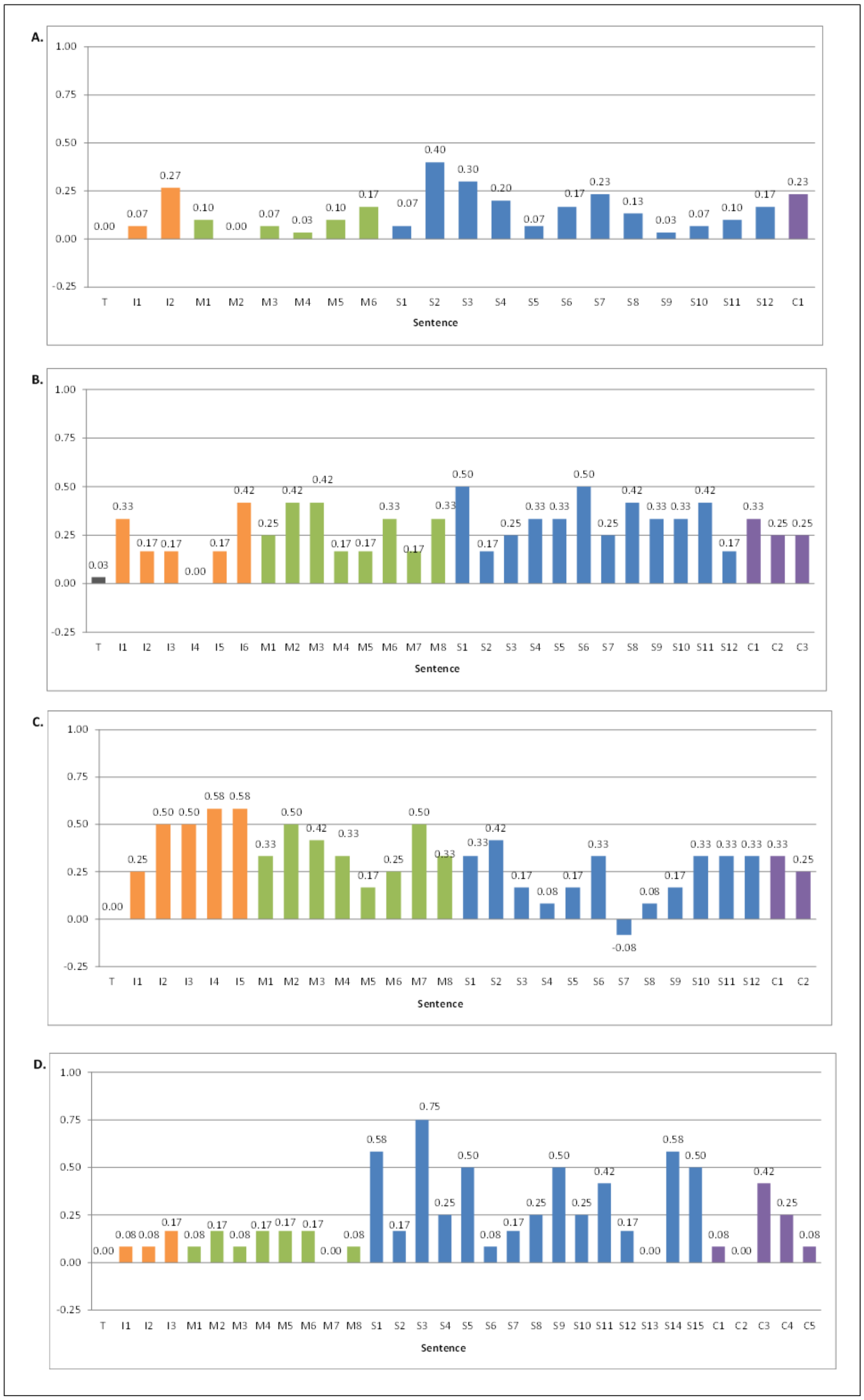

Figure 9. Average sentence scores by explanatory essay from non-expert participants highlighting and underlining.

Each of the four essays are represented as follows: A) frequency of extreme weather, B) increasing rate of carbon dioxide, C) enhanced greenhouse effect, and D) difference between weather and climate. The average scores for each sentence were calculated based on sentences being marked as being “liked, accurate, or clear” (+1), “disliked, inaccurate, or unclear" (-1), and not marked at all (0). The closer to 1, the more positive on average the essay was rated while the closer to -1, the more negative the essay was rated; near 0, the essay had mixed ratings throughout. Sentence abbreviations and colors correspond to T = title, dark grey; I = introduction, orange; S = science, blue; M = metaphor, green; and C = conclusion, purple.

Clarifying non-expert reactions

The interviews elicited a mix of positive and negative responses to each essay as well as to each metaphor. In discussing the essays, participants expressed that they liked the essays particularly because they found the essays to be interesting, helped them learn something new, identified areas that were clear and easy to understand, and felt the content was familiar or relatable. On the other hand, negative responses included confusion regarding certain aspects of the essays, identified where more information was needed, and skepticism or uncertainty about the science. Table 2 and Table 3 summarize the thematic content of the statements made overall for the essays by the non-expert participants. The themes are highlighted with examples from the interviews and further discussed below. Positive reactions specifically for the metaphors were similar to the full essay themes. Participants discussed the general likability of the metaphors because they were clear and helpful with their understanding of the topic, relatable, and were able to visualize what they were reading (Table 4). Conversely, some participants disliked some of the metaphors, and found them to be a distraction, unhelpful, confusing, or oversimplifications (Table 5).

Table 2. Summary of positive reactions to explanatory essays across total non-expert sample.
In reviewing the positive and negative reactions to the essays, several themes emerged. A '✓' indicates a statement(s) made by a participant was corresponded to the theme.

Participant #	Positive			
	Liked and interested	*Helped with learning*	*Clear and easy to understand*	*Familiarity of topic*
1	✓		✓	
2	✓	✓		
3	✓	✓	✓	
4	✓			✓
5	✓	✓	✓	✓
6	✓	✓	✓	
7	✓	✓		
8	✓		✓	
9	✓		✓	
10	✓	✓		✓
11	✓	✓	✓	
12		✓		
13		✓		
14	✓	✓	✓	
15		✓		
16	✓	✓	✓	✓
17			✓	
18			✓	✓
19	✓	✓	✓	
20	✓	✓		
21	✓	✓	✓	
22				
23	✓	✓	✓	✓
24		✓		
25				
26	✓	✓	✓	
27			✓	✓
28			✓	✓
29	✓			✓
30	✓	✓	✓	✓

Table 3. Summary of negative reactions to explanatory essays across total non-expert sample.
In reviewing the positive and negative reactions to the essays, several themes emerged. A '✓' indicates a statement(s) made by a participant was corresponded to the theme.

Participant #	**Negative**		
	Confusing	*More information needed*	*Skeptical or uncertain*
1	✓		
2		✓	
3			
4			✓
5			
6		✓	✓
7	✓		
8	✓		✓
9			✓
10	✓		
11			✓
12			✓
13	✓		
14		✓	
15			✓
16			
17			
18		✓	
19	✓		
20		✓	
21	✓		
22		✓	✓
23	✓		
24	✓		✓
25		✓	✓
26			
27			
28	✓		
29			
30		✓	

Table 4. Summary of positive reactions to metaphors of the explanatory essays across total non-expert sample.
A '✓' indicates a statement(s) made by a participant was corresponded to the theme. Each topic and metaphor is unique, and some participants preferred some metaphors to others.

Participant	Extreme Weather				Carbon Dioxide				Greenhouse Effect				Weather & Climate			
#	*Liked*	*Clear*	*Relatable*	*Visualize*	*Liked*	*Clear*	*Relatable*	*Visualize*	*Liked*	*Clear*	*Relatable*	*Visualize*	*Liked*	*Clear*	*Relatable*	*Visualize*
1	✓	✓				✓										
2	✓	✓	✓				✓	✓				✓			✓	
3	✓	✓	✓		✓			✓		✓				✓	✓	
4		✓								✓						
5										✓			✓			
6									✓	✓			✓			
7	✓	✓			✓				✓							
8					✓	✓		✓	✓	✓						
9	✓									✓		✓				
10					✓						✓		✓	✓		
11					✓		✓	✓	✓		✓					
12		✓				✓								✓		
13	✓	✓				✓			✓		✓				✓	
14	✓				✓	✓			✓		✓					
15	✓	✓	✓		✓					✓						
16	✓				✓			✓	✓			✓				
17	✓								✓		✓		✓			
18	✓					✓			✓				✓			
19					✓				✓	✓		✓	✓			
20																
21											✓		✓			
22											✓					
23	✓	✓			✓	✓			✓	✓		✓	✓			
24						✓							✓			
25																
26								✓		✓		✓	✓			
27	✓				✓				✓	✓				✓	✓	
28					✓			✓								
29		✓				✓							✓			
30	✓				✓				✓		✓					

Table 5. Summary of negative reactions to metaphors of the explanatory essays across total non-expert sample.
A '✓' indicates a statement(s) made by a participant was corresponded to the theme. Each topic and metaphor is unique, and some participants preferred some metaphors to others.

Participant	**Extreme Weather**				**Carbon Dioxide**				**Greenhouse Effect**				**Weather & Climate**			
#	*Dislike*	*Unhelpful*	*Distracting*	*Confusion*	*Dislike*	*Unhelpful*	*Distracting*	*Confusion*	*Dislike*	*Unhelpful*	*Distracting*	*Confusion*	*Dislike*	*Unhelpful*	*Distracting*	*Confusion*
1				✓				✓								
2																
3																
4	✓	✓														
5																
6	✓	✓														
7																
8			✓												✓	
9		✓														
10																
11	✓	✓											✓	✓		
12																
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15																
16																
17						✓										
18	✓					✓										
19						✓	✓	✓								
20																
21				✓						✓						
22				✓		✓	✓						✓	✓		
23																
24										✓					✓	
25						✓				✓						
26																
27																
28										✓			✓			
29			✓			✓				✓						
30										✓						

Positive responses to essays overall

The majority of participants commented that overall they liked the essays and found them to be of interest. Some of the main reasons why they liked the essays included the flow of the essay and the presentation of the information. Participant 13 summed her overall reactions to the essays stating, “I like how all of these are written. They're very bite size, easy to understand... And you're able to get, you know, the information.” Another reason participants positively reacted to the essays, expressing they learned something:

> *Participant 2 [the rate at which carbon dioxide is increasing]: [I]t went into you know more depth of you know understanding the carbon dioxide in the atmosphere and how it's affecting everything... Like this part I thought was cool. Carbon dioxide levels when they're high, the 300 ppm or higher. The example that's when the sea ice starts melting and the weather starts changing and that's when everything starts to melt. I didn't know that. That's new for me. I thought that was interesting because I didn't know that.*
>
> *Participant 30 [the enhanced greenhouse effect]: I thought it was great and learned about was I always thought the greenhouse effect was bad but I think the first sentence or the second sentence in the first paragraph says it is the natural heating process... So that was good and so it isn't necessarily the greenhouse effect that's the issue it's more the enhanced greenhouse effect which is making things worse and that was a good thing to know. Something that I learned new.*
>
> *Participant 15 [the difference between weather and climate]: I think that once again I never thought about the difference between weather and climate and you point out very well the difference.*

In the discussion about the essays it was particularly important to observe that, at least in the moment, previously mentioned misconceptions (i.e. ozone depletion, equating weather and climate) were not re-articulated and in some cases acknowledged that their knowledge was corrected or improved.

It was a pleasant surprise to find that almost half of the participants had some familiarity with the topics of the essays. For example,

> *Participant 18 [the rate at which carbon dioxide is increasing]: I mean I've heard all of it before so it's you know making the point explaining how the carbon dioxide goes up and why it's has a relationship to the temperatures. And where the CO_2 is stored.*

Participant 19 in particular discussed how he was familiar with the topics but the essays he had read thus far articulated what he had attempted to describe earlier in the interview but not quite in the same way:

> *I think it was just reinforcing what I knew but other ways to explain it and describe it where like some of the other ones like the greenhouse effect and greenhouse gases, those things aren't in my working vocabulary or my experiences.*

Positive responses to metaphors

With regards to the reactions of the metaphors, positive reactions varied across the four essays, though all received some positive commentary. More than two thirds of the non-experts stated they liked at least one of the metaphors, for one reason or another (Table 4). For the frequency of extreme weather events and the rate at which carbon dioxide is increasing essays, the metaphors were clear and helpful in explaining the topics. Participant 12 found that the comparison made between the baseball player on steroids and the greenhouse gases in the atmosphere was an obvious comparison and made sense:

> *I think it's the methodology. Apply statistics before and after he started to take steroids and you're looking at the same thing in terms of the heat standpoint I guess so carbon dioxide before and after which makes sense, obviously.*

Participant 1 explained that comparing the buildup of carbon dioxide in the atmosphere to an overflowing tub was clear and made the explanation easy to understand:

> *It was just, it was really clear about the unbalance using the tub as the earth. And so I just thought that was really clear and it made it easy to understand.*

In some cases, it was articulated that the metaphor was helpful to their understanding of the greenhouse effect; for example, Participant3 stated: "I just kind of understood that the first sentence with the parked car effect lets sunlight in. I understand that already and all I needed." They continued explaining that they had experienced a car being hot: "It's relatable." The relatability of a metaphor was also a theme mentioned for the frequency of extreme weather events essay. Participant 2 explained,

> *[W]ell I highlighted the first passage, well first paragraph, talking about the homeruns because I thought that was really helpful comparison. Like it was sort of relatable in the that respect talking about the scientific method how you can determine if it is effecting it or not effecting it.*

Participant 23 made a reference to how making comparisons to what people hear about in the media about other topics can make an unfamiliar topic more relatable (in reference to the frequency of extreme weather event essay):

> *Well I think because there's been so much publicity around steroids and batting statistics and I'm no sports fan so the fact that I know that it just anyone who*

reads the paper would know it. It's not just the sports page. And so it just gives a different example that take a more not a more concrete but just a concrete example that you can compare to what you're talking about.

In adding to their commentary regarding the use of metaphors, a few participants mentioned that the metaphor in the passage helped them visualize the associated scientific phenomenon. Specifically talking about the carbon dioxide bathtub metaphor, Participant 28 stated:

> *Well we all know what a bathtub looks like and we can visualize it and we can imagine carbon as water and it's relatively easy to grasp... It's just how to think of the amount of carbon in the atmosphere.*

Participant 26 also found the comparison of the parked car effect to the greenhouse phenomena to not only be relatable but that they could visualize the effect, imagining how they had felt getting into their own car:

> *Well I mean you can visualize that. And you understand that it's just like letting a car sitting out in the sunlight where it has no place for the heat to dissipate, it starts building temperature.*

While this was a less common theme, it is particularly interesting that some participants mentioned visualization. The ability to visualize a process through a metaphor has been observed and addressed in other studies as well (Hamill et al., 1980; Mayer, 1993; Zaltman, 2003).

Negative responses to essays overall

While the positive reactions were beneficial in understanding what participants liked and what parts of the essay facilitated an individual’s learning, the negative reactions were critical in determining what components required revisions to increase the usefulness of each essay's content. There were a few important terms and phrases that caused people to be confused and seek clarity. For example, several participants asked about how global warming could result in colder temperatures or more extreme winter storms:

> *Participant 12: I don't understand how global warming affects cold weather, more intense cold when everyone is telling us how everything is affecting how warm and how it's trapping heat. You can't be trapping heat and freezing to death at the same time. So I have a little issue with that. I don't know much about what causes the cold weather to come in. That's another thing you have. You have cold weather and you have melting ice cubes, icebergs in the water, which doesn't make a whole hell of a lot of sense to me. How can you have two extremes at the same time?*

> *Participant 7: I know it's severe heat being trapped in the atmosphere but I understand the floods and even the droughts but I don't how it creates extreme winter storms.*

During the discussions about the frequency of extreme weather events, it was evident that participants had heard about extreme weather events, but mostly – if not solely – made the connection of extreme heat or precipitation events, and excluded extreme cold or winter storm events. This is perhaps related to the misunderstanding that weather and climate are the same concept, which surfaced at the start of the interviews and has been observed by other researchers (Lombardi & Sinatra, 2012; Read, Bostrom, Morgan, Fischhoff, & Smuts, 1994). However, this confusion and misconception did not recur after reading the fourth essay about weather and climate.

Other factors that contributed to confusion included being overwhelmed or intimidated by some of the more technical aspects of the essays. After reading the increasing carbon dioxide essay, Participant 7 addressed how the details regarding where carbon is stored and how it is released is complex: “It [is] kind of confusing. I’m like horrible with technical science terms.” Participant 19 agreed and compared the increasing carbon dioxide essay (read second) to the first essay, the frequency of extreme weather events, stating “[this] was a little harder for me to grasp.”

Other participants also felt that there was some information missing. There were pros and cons to acknowledging that some expected details were not present. For example, excluding information about specific actions that people can take to mitigate or adapt to climate change may encourage people to seek out such information. However, there is a possibility that individuals would not take that next step of searching for that information, hence one reason why the “more information needed” theme is classified as a negative reaction. Participants 6 and 21 were hoping to find some kind of information about solutions to climate change, or actions that they or others could be taking:

> *Participant 6: I mean in that it talks more about what we're doing is specifically contributing but it doesn't speak about at all what we're doing to mitigate it because there are a lot of things that we're doing to mitigate it.*
>
> *Participant 21: I don't know what I can do about that so it's one of those things is I can recycle but I don't think that is going to help the gases but and then this one this is how they're summarizing here that says it is increasing the frequency and the severity.*

Some participants in the end did allude to or stated that they felt motivated to seek additional information. While the intention of the essays were to help individuals better understand climate change concepts better, it is interesting to note that the act of reading the essays lead a few to be interested in finding out more about what can be done about climate change.

References or citations to studies were also identified as missing information in the essays. For example, Participant 22 would have liked to have seen a study cited for some of the facts:

> *I think it would be helpful at least for me when statements are made like the average temperature would be 50 degrees Fahrenheit cooler, and comments like since 1900 the atmosphere has increased the carbon dioxide in the atmosphere has increased by 40% and all of this. I guess it would help if I saw some sort of study.*

Such commentary often led participants to segue into discussing skepticism or uncertainty about the scientific components of the essays; and yet another reason why the theme of "more information needed" was classified as a negative reaction. Skepticism or uncertainty with respect to the explanations stemmed from statements which included the time frame from which data was collected, the fact that society is more connected than ever before, and instruments that scientists use to take measurements have changed overtime.

> *Participant 6: Are they happening more frequent? I feel like that we go through patterns. I mean there were a lot of summers where there were droughts. There was a summer where I worked for Jiffy Lube and I could have sworn it was the worst summer ever. It was so hot outside and we were outside and it was terrible.*

And it was just an average summer. It is just how we perceive it. I feel like there are just patterns over 50 years, 100 years. I don't know what the pattern is; it could be that we have a similar year 50 or 60 years ago.

Participant 11: This I don't know what to do with this paragraph here. I don't think that comparing weather in the last 50 to 100 years to what we have today is really a long enough period to reach certain conclusions. I think that the there's always variation in weather you know.

Participant 22: Why are they observing it more? Well I just think people are more, just like [with] food and diet, and it's all kind of what's going on in society. We're becoming more aware... we're a little more sophisticated as time goes on.

Participant 25: I mean I have a hard time, I understand that they use instruments. I understand all of that and those instruments could have wrong data and they could be used for wrong. The second thing is when you get down to analyzing it; it's doing whatever they want it to do.

Negative responses to metaphors

Commentary regarding the metaphors also received some more pointed, negative reactions despite the previously mentioned positive reactions. Half of the participants stated they disliked either the frequency of extreme weather events or the difference between weather and climate metaphors – both of which involved baseball comparisons. The dislike for these particular metaphors was rooted in strong feelings about and personal connections to baseball, finding it to be a bad analogy, and that it "dumbs down" the reader.

Participant 4: Well there's one point about the baseball analogy... It's a bad analogy and I'll call out Barry Bonds. I firmly believe he took PEDs and took stuff that definitely helped him but I definitely believe he would have been in the hall of *fame and would have hit 500 homeruns had he not done anything. He just had that [ability]; he was a freak.*

Participant 25: I don't know how they're using this comparison [baseball player on steroids and increasing frequency of extreme weather events]. This is a not apple to apples, this is apples to oranges.

Participant 28: The difference between weather and climate, the baseball analogy, I don't really like it because I think it dumbs down the reader and you can't understand this unless I put it in terms of popular culture that your small brain is accustomed to dealing with. I think it's insulting.

Some participants described the metaphors as unhelpful to their understanding and/or distracting. Participant 29 expressed that comparing the enhanced greenhouse effect to a parked car in the summer sun was clear, but it did not help him understand the concept any better: "Again so the second [paragraph] was just speaking metaphorically. Did I understand it? Yeah but you know it was sort of cartoonish." A few others reacted similarly to the frequency of extreme weather, as well as the rate of increasing carbon dioxide metaphors, though they were more specific explaining the metaphors were a distraction:

Participant 8 (extreme weather): It kind of got me off track.... To compare climate change and the steroids and the baseball game that just threw me off. Maybe it's a personal thing.

Participant 19 (increasing carbon dioxide): Yeah that could be just from a teacher's perspective. If I'm looking at this who is somebody who is not scientifically, that could be a distractor to helping me understand all of that.

A few other participants found the metaphors to be confusing. For example, Participant 21 was confused by the introduction of baseball and steroids into a passage that they were initially told was about the frequency of extreme weather and climate change:

> *Well first of all when I started I didn't know what steroids in baseball had to do with the environment. And then it says it's similar to what climate scientists look at but I still don't you know they call it the steroids of the climate system, greenhouse gases, are the steroids, I don't know what that means. I mean maybe I don't understand what steroids are. I do know they make you stronger but what does that got to do with a climate system.*

Participant 30 came to the conclusion that the base concept, the window panes of the car, mapped to the target concept, the greenhouse gases, but was then confused by a follow-up statement at the end of the paragraph that acknowledged the heat in the car and the heat in the atmosphere are the same result, but of different [unnamed] mechanisms:

> *I'm not sure how the window or the glass pane in the car are the same as like the greenhouse gases. Like it make me think are there greenhouse gases inside the car? Or but then it mentions that it is a different mechanism.*

These points of confusion when reading the metaphor counteracted the explanatory purpose of the metaphor and participants developed several questions to gain clarity of what they had read. Asking questions to better understand the topic is good, but had the passages been read independently outside of an interview setting, the questions may not have been asked or answered.

What and how lay audiences explain climate change to others

While participants thoughtfully discussed and critiqued the essays and metaphors, there were only a few cases where the non-experts re-articulated or exclaimed they would use the metaphor to explain climate change to a family member or friend. Ten of the 30 participants said they would try using the “parked car effect” metaphor when explaining the greenhouse effect. However, some participants had more success at rearticulating the explanatory metaphor than others. Participant 30 stated that they liked the explanation of the parked car much better than the greenhouse metaphor and might explain the greenhouse effect to someone by saying: “...remember how it is to be in your car right after you park it in the sunlight after a few hours? The glass is like the greenhouse gases, something along those lines. And it gets hot.” And from there she would see where the conversation went. Participant 7 also said she would use the parked car metaphor and placed an emphasis on why the enhanced greenhouse effect and climate change is an urgent issue:

> *I couldn't really explain to someone what is going on that well any way because of my lack of knowledge but if I were to sum it up I would say technically the car in the middle of summer and all that heat, nothing is going out, if we're just absorbing all this heat you know, we're bound to have negative effects. And that's why you don't leave your pets in the car or your baby.*

The baseball statistics metaphor for explaining the difference between weather and climate was not mentioned when participants explained the concepts themselves. However, the carbon dioxide bathtub and the baseball player on steroids metaphors were each explained by one participant:

> *Participant 8 (carbon dioxide bathtub): I would just say that the, think of the world as a bathtub, as you used in there. And I would really turn on the faucet and say this is the CO_2 production that we are producing by driving cars, flying jets and these things and I would let the faucet go. But at the same time I would*

> *block it a little bit so that the outgoing wasn't as much as the incoming water and then when it overflows that this water you can think of it as heat.*
>
> *Participant 27 (baseball player on steroids): I would use the baseball player at one time at the plate and then I would say for weather and for climate I would say the batting average with all the taking steroids or not, and the weather is getting worse...* [Articulating her side of a hypothetical conversation with a friend] *You watch baseball right? I'd say did you see an improvement in such and such a player's performance? Throwing longer, hitting harder? Probably will say yes. So do you think this person is on steroids? Well it's a possibility. Well what if he were on steroids you would see a difference in that, correct? Okay well let's take that analogy and put it into climate change. If we put all of these poisonous gases into the greenhouse effect, if we call them the equivalent of steroids in the baseball player and the performance is better [and] then wouldn't, then well my analogy isn't doing so well. Then wouldn't these steroids cause more weather events to happen? Then they would say what the heck are you talking about? So then I'd probably be quiet.*

Including the selected examples above, still only one-third of the participants re-articulated the metaphors in the essays – some more successful and confident than others. All participants – with the exception of one – predominantly relied on facts or the more technical, scientific information in the essays. In explaining the four different concepts and climate change more broadly, none of the participants re-visited the earlier two misconceptions: ozone depletion, and equating weather and climate. Eight participants also incorporated and emphasized the human caused component of climate change, while four addressed that while climate change is a problem, there are solutions to the problem and that we have some control over the situation.

There are perhaps a couple of reasons why participants chose not to subsequently use the metaphors presented to summarize their post exposure understanding of each of the four climate change concepts presented. The first is that the metaphors actually helped with the understanding of the more technical information and participants felt more confident explaining at a higher level than in the beginning of the interview. The second reason could be that the selected metaphors, while mostly liked and found to be clear, were not necessarily memorable or easy to re-articulate and is counter to the previously reviewed literature.

The previously singled out individual however relied on observations and partial conclusions derived independently from the interview session itself, only explaining climate change essentially as a scientific hoax, and acknowledging the information in the essays as biased or untrue. This occurrence can be summed up with one the subject's more general responses:

> *Well climate change is two things. First of all you have the people who are trying to make who are saying the climate is changing, the scientists using all of this theory who are saying we are in trouble and who are saying we have to adjust our living and adjust certain things. [Second] the climate is changing... And God does strange things and God is in charge of the weather. And if he wants to change it, he can change it.*

4.4 Conclusion

Conducting non-expert interviews makes it possible to explore how non-experts perceive and understand climate change, as well as relevant concepts before and immediately after exposure to explanations using metaphors. The mental models of climate change initially were not entirely clear and sometimes inaccurate. However, initial explanations demonstrated a level of awareness of the issue, yet often included a statement that they knew little about climate and/or were not confident in what they knew. After reading the essays, explanations were comprised of more details, included information that had been read, and most participants appeared more confident in their knowledge or indicated misconceptions were corrected. Most explanations focused on the "hard science," though a third of participants did attempt re-articulating one of the metaphors. However, by examining the metaphor paragraph reactions quantitatively and qualitatively, there is some evidence that the metaphors helped to make the climate science more comprehensible to the non-expert participants.

This study involving non-experts in combination with the expert exploratory study of the previous chapter has been used to inform the message testing survey of which the results are presented in the following chapter. The positive reaction themes that emerged throughout the interviews for the essays and the metaphors are promising in that metaphor is a beneficial communication technique in the climate change discourse. However, the negative reactions to the metaphors motivated some significant revisions to the essays. To remedy unhelpfulness, distraction, and confusion created by some of the metaphors, the essays were edited before using them in the stimulus materials for the message testing study. More specifically, two of the metaphors were replaced with new metaphors for subsequent use: the parked car effect metaphor was replaced with the blanket metaphor for the enhanced greenhouse effect essay; and the baseball statistics metaphor was replaced with the mood and personality metaphor for the difference between weather and climate essay. These new metaphors were also selected as alternatives per the suggestion of the experts made by more than one expert in the previous study. The feedback received also indicated that in some way (e.g. causing confusion) each metaphor “broke down” – some more than others – and did not add value to the essay. Other researchers have observed this effect of metaphors breaking down and have cautioned researchers, educators, and communication practitioners (Guerra-Ramos, 2011; Mason, 1994). In the first study, a metaphor not being a perfect fit or “falling apart” was a concern of some experts and a reason why they only use a metaphor if it is an accurate metaphor they feel comfortable with using.

CHAPTER 5. STUDY 3 – CLIMATE CHANGE METAPHOR MESSAGE TESTING EXPERIMENT

5.1 Introduction

This message testing experiment was conducted to build upon the results of both of the qualitative studies presented in the two previous chapters and improve on the experimental design of the pilot study. This study also completes the sixth step recommended by Morgan and colleagues (2002) for developing effective messages targeted towards non-experts: (step 6) test messages developed based on the information gathered. Before testing the messages developed, considerable improvements were made to the stimulus materials by leveraging insight derived from the previously discussed interviews with experts and non-experts (steps 1 through 5). From the expert interviews, each essay's accuracy was improved and incorporated content that was more practical so that the messages were overall more ecologically valid. For example, the original metaphor used in explaining the difference between weather patterns and climate change was replaced by a more commonly used metaphor: the outcome of a baseball player up at bat and the player's batting average was replaced with a metaphor that compares weather and climate to one's mood and personality. While the non-expert interviews were predominantly comprised of positive commentary, there were clear instances of unhelpfulness, distraction, and confusion that required revision to not only improve the clarity of the science but also of the metaphors. The survey design was also improved by measuring understanding of the climate change concepts – a focal dependent variable – through open-ended response items, replacing forced response questions. The open-ended questions allowed for the participants to answer in more detail and to provide insight into how the participant understood the essay, as opposed to a forced-response question to which there is a right and wrong answer(s).

The primary purpose of this study was to determine if metaphors increase the understanding of climate science concepts, and if metaphor usage also influence beliefs about climate change. Empirical research has shown that metaphors can help audiences better understand complicated scientific concepts. A growing number of metaphors are used to explain various climate science concepts (Atanasova & Koteyko, 2015; Guy et al., 2013; Russill, 2011), but the only empirical evaluation of climate metaphors to date (van der Linden et al., 2014) found that medical and bridge safety metaphors did not enhance the effectiveness of a simple corrective statement about the scientific consensus on human-caused climate change. However, a recent series of studies have demonstrated that a mechanistic explanation of the greenhouse effect – how global warming works – does increase the understanding and acceptance of climate change (Ranney & Clark, 2016; Ranney et al., 2012). Furthermore, a meta-analysis has highlighted the importance of testing and selecting metaphors that leverage the familiarity of a base concept in order to enhance the understanding of a target concept (Sopory & Dillard, 2002). This is particularly the case wherein a base concept contextualizes the target concept that the audience is less familiar with and knowledgeable about. A lack of familiarity of the base concept can lead to lower levels of comprehension, and an audience being left misinformed (Gentner & Markman, 1997; Guerra-Ramos, 2011).

Following from the two qualitative study findings, experimental design considerations, and the literature reviewed, the survey for the climate change metaphor message testing experiment was designed to evaluate if using metaphors was a beneficial approach to explaining climate change concepts. More specifically, the following hypotheses are investigated in this chapter:

> **H1:** *The combination of science and metaphor to explain a climate change concept will lead to favorable changes in individuals' understanding; and metaphor or science alone will result in a less favorable change in understanding. (S+M > M > S)*
>
> **H2:** *The combination of science and metaphor to explain a climate change concept will lead to favorable changes in individuals' belief certainty that climate change is happening; and metaphor or science alone will result in a less favorable change in belief certainty. (S+M > M > S > C)*
>
> **H3a:** *The more familiar the base concept is, the more effective the inclusion of a metaphor will be in improving understanding of the concept.*
>
> **H3b:** *The more familiar the climate science concept (target) is, the less effective the inclusion of a metaphor will be in improving understanding of the concept.*

5.2 Methods

Sample

The message testing survey was fielded with a soft launch of 100 participants on August 2, 2016, and the remainder of the sample was collected between August 3rd and August 15, 2016. In total, 1,523 individuals completed the survey (Table 6) and were each randomly assigned one of the 13 message treatments. Qualtrics fulfilled recruitment for the online survey via email. Participants were invited to complete the survey and upon finishing would receive points (equivalent to approximately $5.00) for completion. The points participants receive for survey completion accumulate and can be put towards gift cards, airline miles, and other rewards options. On average, it took participants 21 minutes to complete the entire survey. The sample requested and received from Qualtrics was a quota sample matched to census data on two demographic variables: gender and age. Additional demographic information was also collected at the conclusion of the post-test questionnaire (Table 7).

Table 6. Number of participants per message condition.
Participants were randomly assigned to one of the thirteen message treatment conditions; 115 were assigned the comparison treatment. In total, there were 1523 participants who completed the survey.

	Science Only	**Metaphor Only**	**Science + Metaphor (Combination)**
Frequency of extreme weather events	102	121	110
Rate of CO_2 entering the atmosphere	111	118	125
Enhanced greenhouse effect	131	119	115
Weather, climate, and climate change	117	135	104

Table 7. Descriptive statistics for demographic variables.
Two variables were matched to census data: gender, and age.

Variable		*n*	*%*	*US %*
Gender	Male	701	46	48
	Female	820	54	52
Age	18-24	127	8.3	12
	25-34	288	18.9	18
	35-44	268	17.6	17
	45-54	287	18.8	18
	55-64	268	17.6	17
	65+	285	18.7	18
Education	Less than high school	21	1.4	
	High school	323	21.2	
	Some college	399	26.2	
	Associate's degree	424	27.8	
	Bachelor's degree	177	11.6	
	Graduate degree	179	11.8	
Ethnicity	Hispanic, Latino, or Spanish origin	111	7.3	
	Not Hispanic, Latino, or Spanish origin	1395	91.9	
	Prefer not to answer	12	0.8	
Race	White	1236	81.4	
	Black, African American	149	9.8	
	American Indian, or Alaska Native	14	0.9	
	Asian	57	3.8	
	Pacific Islander	4	0.3	
	Other	45	3.0	
	I prefer not to say	13	0.9	
Income	$24,999 or less	377	24.9	
	Between $25,000 and $49,999	439	29.0	
	Between $50,000 and $74,999	324	21.4	
	Between $75,000 and $99,999	36	2.4	
	Between $100,000 and $124,999	178	11.8	
	Between $125,000 and $149,999	93	6.2	
	Between $150,000 and $174,999	42	2.8	
	$175,000 or more	23	1.5	
Political Ideology	Very conservative	122	8.0	
	Conservative	240	15.8	
	Somewhat conservative	191	12.6	
	Moderate, middle of the road	535	35.2	
	Somewhat liberal	162	10.7	
	Liberal	161	10.6	
	Very liberal	108	7.1	

Survey design

The study involved four climate change topics and three explanation types, the experimental design was a 3x4 factorial design resulting in 12 message conditions (Table 8). One additional message condition served as a comparison group (13^{th} essay). An *a priori* power analysis, calculated using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007), indicated that 1521 individuals (117 per condition) were necessary for 95% power when detecting a small effect size for an alpha of .05.

Table 8. Experimental design.
The 3x4 experimental design includes a total of 12 treatments. One additional message treatment was included for a comparison group, thus there were a total of 13 different message treatments.

	Science Only	**Metaphor Only**	**Science + Metaphor (Combination)**
Frequency of extreme weather events			
Rate of CO_2 entering the atmosphere			
Enhanced greenhouse effect			
Weather, climate, and climate change			

To assess the effects of metaphors used to explain climate change concepts, a 29-item questionnaire was developed with three distinct segments: a pre-test questionnaire, explanatory essay, and a post-test questionnaire (Figure 10). The pre-test consisted of 12 questions presented before exposure to an explanatory essay, and the post-test consisted of a maximum of 16 questions, some of which were repeated from the pre-test. The survey items were derived from literature previously reviewed regarding the effectiveness of metaphors in explanatory contexts, as well as the Climate Change in the American Mind survey series (Leiserowitz et al., 2015). The pre- and post-test each included an attention check item as confirmation that individuals were paying attention and reading the questions. If a participant failed an attention check item Qualtrics did not record any further responses for the individual, they were eliminated from the survey, and were replaced by another participant. The essay rating immediately following the essay was included to mimic a more realistic scenario of reading an article and served as somewhat of a distracting task after the message treatment prior to the post-test questions (Ratner & Riis, 2014). Only the measures analyzed in this study are detailed below. A copy of the full survey instrument is included in Appendix C. Study 3 Materials. Approval for primary data collection procedures was received from the Institutional Review Board (IRB) at George Mason University.

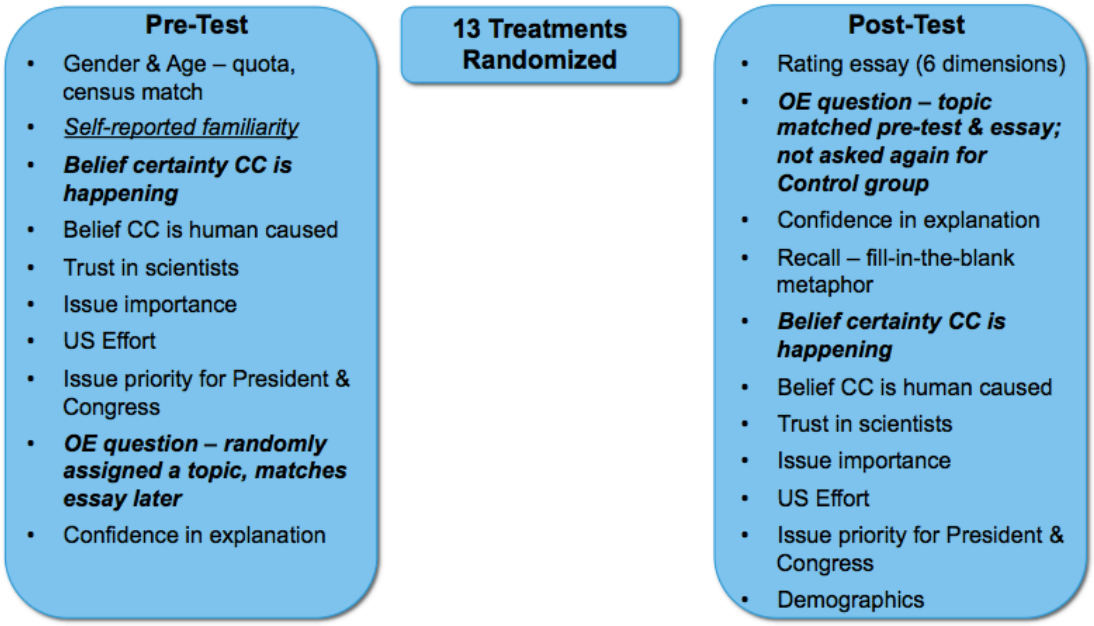


Figure 10. Overview of survey design and instrument.
The survey consisted of three main segments: a pre-test questionnaire, an explanatory essay randomly assigned per participant, and a post-test questionnaire (OE = open-ended; CC = climate change).

Measures

The analyses presented in this chapter involve two key independent variables (essay topic and explanation type), two dependent measures (understanding and climate change belief certainty), and two covariates (familiarity of base and target metaphor concepts).

Essay topic and explanation type

As mentioned previously, each participant was assigned one message treatment, which involved one climate change concept expounded upon using one explanation type. There were a total of four topics: 1) the frequency of extreme weather events; 2) the rate at which carbon dioxide is increasing; 3) the enhanced greenhouse effect; and 4) weather, climate and climate change. These topics persisted through all three studies and were selected because they are concepts experts often explain during formal and informal communication (according to expert interviews), they receive some media attention, and/or are topics that are misunderstood or misperceived by non-experts. Moreover, there are prospectively useful metaphors, which correspond with these four topics. The three explanation types were: science, metaphor, and a combination of the science and metaphor explanations. Incorporating three explanation types allowed for a comparison to be made between literal language (scientific terminology and jargon) and metaphorical language, as well as for the investigation as to whether or not metaphor use can support and enhance the scientific explanation, hence creating a stronger explanation than science or metaphor explanations alone.

Understanding

Measuring understanding of climate change before and after reading an explanatory passage was of interest because metaphors, in comparison to literal language, have had both positive and negative effects on non-experts' knowledge in different contexts (Ait El Houssi et al., 2004; Galesic & Garcia-Retamero, 2013; Glynn & Takahashi, 1998; Guerra-Ramos, 2011; Mason, 1994; Roehm & Sternthal, 2001). Additionally, explaining the science of how global warming works through enhancing the greenhouse effect in a mechanistic process was demonstrated to positively benefit individuals' knowledge of climate change (Ranney & Clark, 2016), thus it was important to formally examine whether a metaphorical explanation in fact is better or worse for enhancing comprehension of the greenhouse effect, and other climate change concepts. Understanding of climate change concepts was measured through scoring open-ended question responses, both before and after reading one of thirteen essays. The only exception to this was the comparison group, which was only asked an open-ended question before reading the essay, as there was no reason to think their response would change after reading the comparison essay.

The question varied depending on the topic the participant was assigned. The question item asked for participants to write one to three short, simple sentences (about 30 words or less) that explains one of the four topics: 1) how scientists know that increasing greenhouse gases in the atmosphere are causing more frequent extreme weather events; 2) how scientists know that increasing levels of CO_2 in the atmosphere is causing global warming; 3) how global warming is happening; and 4) how scientists know that climate change influences our weather. The comparison group was asked about how global warming is happening. For the pre-test, participants were instructed that if they did not know how to explain what was asked, they could write, "I don't know." However, for the post-test question, that was not included in the question prompt; instead at the beginning of the prompt, participants were asked to think about what they read and then to write an explanation for the topic just read.

Each response was scored on a zero to seven scale based on five criteria including: whether the question was addressed in the response or attempted to be answered, the details included in the response, correctness of the response, connections made between concepts in the response, and overall explanation clarity. Each open-ended response was scored according to the rubric (Table 9), and a change in knowledge score was calculated to determine by how much an individual's understanding was changed after reading one of the randomly assigned message treatments. The change in participant's understanding was calculated by subtracting the pre-test score from the post-test score. Summary descriptive statistics of pre- and post-test scores, as well as the change in understanding scores for the overall sample are in Table 10.

Table 9. Scoring rubric for responses to open-ended questions, pre-and post-test.
The rubric was used to assign a value to open-ended responses in order to assess the level of understanding a participant had before and after reading the randomly assigned essay and determine the change in understanding.

Score	Description
0	Response is "I don't know" or dismissive in general of climate change
1	Does not address question and provides a vague response (i.e. "Greenhouse gases"). No connections are made between concepts. May include inaccuracies (i.e. "Pollution, ozone hole"). (Sometimes begins with "I don't know.")
2	Does not address question directly and provides a short and superficial list of either causes or consequences of climate change but does not identify them directly as such. No connections made between concepts listed. Includes inaccuracies and/or misconceptions. (Often begins with "I don't know" but attempts an explanation.)
3	Answers question incompletely. Explanation demonstrates awareness of causes and consequences of climate change, but in attempting to make connections to the topic asked about, includes inaccuracies that are at the center of the explanation provided. (Often begins with "I don't know" but attempts an explanation.)
4	Answers question incompletely; demonstrates awareness and understands the gist of concept. Connections between concepts are vague or ideas are incomplete. Includes few inaccuracies.
5	Answers question incompletely and explains the concept using keywords and specific examples related to the topic. Connects causes or consequences briefly and directly to the topic. Includes one minor inaccurate detail, but not central to the explanation.
6	Addresses the question directly with detail that demonstrates awareness and understanding. Explanation provided makes connections between the topic and causes and/or consequences of climate change (i.e. includes example from personal experience of an extreme storm event). No inaccuracies or misconceptions.
7	Addresses question directly with high-level detail that demonstrates awareness and understanding with appropriate examples and keywords/terminology from the passage. Connections are clearly made between concepts; post-explanation uses phrases (including the metaphor) accurately. No inaccuracies or misconceptions are included.

Table 10. Descriptive statistics for pre-test, post-test, and change in understanding across all topics (N = 1523).

	Mean (Std. Error)	*SD*	*Variance*	*Skewness (Std. Error)*	*Kurtosis (Std. Error)*
Pre-test understanding	1.65 (0.042)	1.65	2.73	0.55 (0.063)	-0.61 (0.125)
Post-test understanding	3.01 (0.047)	1.84	3.40	-0.11 (0.063)	-0.69 (0.125)
Change in understanding	1.36 (0.047)	1.83	3.34	0.52 (0.063)	0.015 (0.125)

Belief certainty

Belief certainty about whether climate change is happening or not was of interest also because attitudes about a topic can influence, or be influenced by the content of a message (Ottati & Renstrom, 2010; Ottati et al., 1999; Sopory & Dillard, 2002). More specifically, the previously mentioned mechanistic explanation of how global warming works also influenced climate change attitudes (Ranney & Clark, 2016; Ranney et al., 2012).

Belief certainty was determined using three question items. The first question that participants responded to was: “What do you think: is climate change happening?” If a participant selected, “yes” they were prompted with the following question: “How sure are you that climate change is happening?” However, if they responded “no” to the first question, they were asked: “How sure are you that climate change is not happening?” These two follow-up questions had four response options from “extremely sure” to “not sure at all.” If a participant selected “don’t know” in response to the first question, no follow-up question was asked. Computing belief certainty with the three items results in a nine-point scale where 1 represents "extremely sure global warming is not happening," 5 represents "don't know," and 9 represents "extremely sure global warming is happening." The three items were asked in the pre- and post-test (Figure 11), and a change in belief certainty was calculated subtracting the pre-test score from the post-test score (M = .09, SD = 1.033).

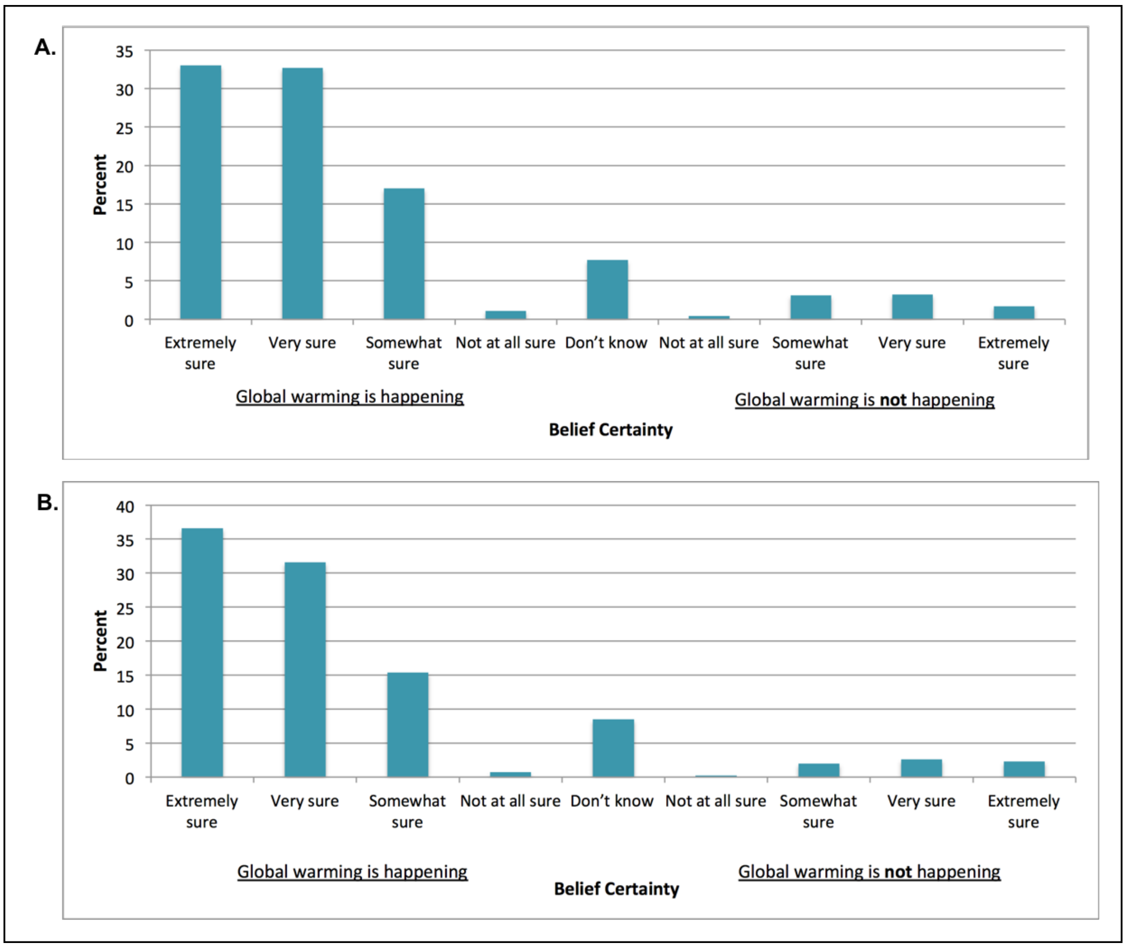


Figure 11. Belief certainty frequencies pre- and post-test for all groups (N = 1523).
Belief certainty was calculated using three survey items. This figure displays the percentage by level of belief certainty that global warming is or is not happening for the full sample, both before and after reading a randomly assigned essay.

Familiarity of base and target concepts

Since familiarity of the base and target concepts of a metaphor influences the outcome of the usage of an associated metaphor (Blasko & Connine, 1993; Gentner & Markman, 1997; Guerra-Ramos, 2011; Sopory & Dillard, 2002), participants were asked to self-report their level of familiarity with each base and target concept at the beginning of the survey. Each participant reported their familiarity for the four climate change topics (target concepts) as well as four base concepts that they may or may not encounter in the essay they would read later. Familiarity was measured on a five-point Likert scale from (1) "not at all familiar" to (5) "extremely familiar." The descriptive statistics for the base and target concepts are presented in Table 11 and Table 12, respectively.

Table 11. Descriptive statistics for base familiarity (N = 1523).

Base Concept	*Mean (Std. Error)*	*SD*	*Variance*	*Skewness (Std. Error)*	*Kurtosis (Std. Error)*
How steroid use effects baseball players	3.16 (0.031)	1.22	1.48	-0.149 (0.063)	-0.916 (0.125)
How water drains from a bathtub	3.97 (0.03)	1.18	1.40	-0.921 (0.063)	-0.196 (0.125)
Additional blankets hold in more heat	3.86 (0.031)	1.20	1.44	-0.806 (0.063)	-0.373 (0.125)
The difference between a person's mood and their personality	3.69 (0.03)	1.18	1.40	-0.645 (0.063)	-0.48 (0.125)

Table 12. Descriptive statistics for target familiarity (N = 1523).

Target Concept	*Mean (Std. Error)*	*SD*	*Variance*	*Skewness (Std. Error)*	*Kurtosis (Std. Error)*
The increasing frequency of extreme weather events	3.39 (0.030)	1.17	1.377	-0.347 (0.063)	-0.717 (0.125)
The rate at which carbon dioxide (CO_2) is increasing in the atmosphere	3.37 (0.033)	1.29	1.669	0.191 (0.063)	-1.066 (0.125)
The "greenhouse effect" (that is, how "greenhouse gases" keep the planet warm)	3.21 (0.031)	1.20	1.430	-0.207 (0.063)	-0.842 (0.125)
Climate change is leading to changes in our weather and climate overtime	3.52 (0.029)	1.13	1.266	-0.449 (0.063)	-0.575 (0.125)

Explanatory essays

Each participant was randomly assigned one essay topic and one explanation type, or the comparison message treatment (Appendix C.2 – Stimulus Materials). The four essay topics remained the same as those used in both expert and non-expert qualitative studies: 1) the frequency of extreme weather events; 2) the rate at which carbon dioxide is increasing; 3) the enhanced greenhouse effect; and 4) weather, climate and climate change. The metaphor only or 'science + metaphor' combination message conditions incorporated a metaphor tailored to one of the four topics, respectively: 1) the frequency of homeruns hit by a baseball player on steroids; 2) the rate at which water enters and exits a bathtub; 3) added blanket layers leads to holding in more heat; and 4) the comparison between your mood and personality. Participants were exposed to these essays after a pre-test questionnaire, and were between 316 to 342 words for the science only essays, 215 to 318 for the metaphor only essays, and 490 to 515 words for the combination essays (Table 13). The comparison essay was a total of 514 words and was written about a topic unrelated to climate change, NASA's Juno spacecraft and mission. These essays had been previously revised based on the expert and non-expert interviews presented and discussed in the previous two chapters. The enhanced greenhouse effect essay 'science only' and 'science + metaphor' essay incorporated the mechanistic explanation of how global warming works via the greenhouse effect from Ranney and Clark (2016). Each essay consisted of a title phrased as a question and a short introductory paragraph. The science-only essays strictly included a science-based explanation, while the metaphor-only essays strictly included a metaphorical explanation, and followed with a summary paragraph. The combination essays included a short metaphorical explanation, a science-based explanation, and concluded with a summary paragraph. The metaphor was placed at the forefront of the combination essay because some evidence has been found that placing a metaphor early in a message influences the persuasive power of the message (Sopory & Dillard, 2002).

Table 13. Essay word count.
The comparison essay word count was comparable to the other 12 essay topics, and was 514 words.

	Science Only	**Metaphor Only**	**Science + Metaphor (Combination)**
Frequency of extreme weather events	316	293	493
Rate of CO_2 entering the atmosphere	333	318	493
Enhanced greenhouse effect	334	215	490
Weather, climate, and climate change	342	292	515

Analyses

The analyses used to evaluate the effectiveness of metaphors in explaining climate change, and answer the research questions posed at the beginning of this chapter involved a series of factorial ANOVAs, one-way ANOVAs, and one-way ANCOVAs.

Assessing change in understanding climate change

To examine how change in the understanding of climate change differs across the four climate change topics and three explanation types, a factorial ANOVA was run. The purpose of this test was to assess the main effect of each independent variable, as well as whether there was an interaction effect between the independent variables. However all assumptions were not met. In particular, the Levene's test statistic was $F\ (12, 1510) = 24.60$, and $p = .000$. Since the test statistic was significant, it indicated that the variances across the four topics did not have equal variances for the dependent variable, change in understanding of climate change. The violation of homogeneity of variance, and the unequal sample sizes for the 13 message conditions, would bias the results of the factorial ANOVA. In an effort to obtain equal variances, all variables involved in the factorial ANOVA were log transformed. However, the Levene's statistic was still significant, $F\ (12, 1510) = 35.863$, $p = .000$, and therefore the assumption that the variances of the dependent variable for all groups are similar was violated. These results lead to the decision to examine each topic separately and run one-way ANOVAs. Generalizations from the results will not be made for explaining climate change, but a discussion can be had about using different explanation types for specific climate change concepts.

The one-way ANOVAs involved the change in understanding of climate change score as the dependent variable, and explanation type as the independent variable. A series of tests, on each, confirmed that the distribution of the dependent variable was normal, the variances of the three explanation type groups were similar, and the independent variable was made up of mutually exclusive groups. Normality was examined by evaluating skewness and kurtosis residuals and Q-Q plots of residuals. To determine if the variance of the dependent variable for all groups was similar, again according to each topic, the F statistic and significance of Levene's test were examined. The details of the tests are documented in the results section of this chapter.

Assessing change in belief certainty

A similar approach was followed to examine change in belief certainty concerning whether climate change is happening differs across the four climate change topics and three explanation types. A factorial ANOVA was performed to test the main effect of each independent variable, and evaluate if there was an interaction effect between the two independent variables. The Levene's test statistic was $F(12, 1510) = 1.596$, and $p = .086$ demonstrating that variance across the topics was approximately equal variances for all groups. However, neither topic [$F(3, 1510) = .417$, $p = .741$] nor explanation type [$F(2, 1510) = .2.61$, $p = .074$] was significant; the interaction effect between the two independent variables was also not significant [$F(6, 1510) = .445$, $p = .849$]. Due to this result, it was also decided to proceed with analyzing the data per topic and perform four separate one-way ANOVAs to examine if for specific topics there was an effect on the change in belief certainty. Again, this allows for a discussion about specific climate change topics not generalizations about using metaphors when explaining climate change.

For the one-way ANOVAs per topic, change in belief certainty was the dependent variable while explanation type was the independent variable. Measures of skewness, kurtosis, and Q-Q plots of residuals were examined to test for normality. The results of the Levene's test equality of error variances determined if the variances for all groups of the dependent variable, belief certainty, were similar. The details of these tests are presented in the results section.

Controlling for base and target familiarity

For each topic, an ANCOVA was conducted to determine if the mean change in understanding score differed based on the explanation type while controlling for the familiarity of the base concept in the metaphor. The same analyses were repeated, controlling for the familiarity of the target concept. The base and target concepts per topic are summarized in Table 14. All assumptions were examined, as summarized in this section, and specified in the results section. Participants were randomly assigned a message treatment; thus all observations were independent. As per to Levene's test, the homogeneity of variance assumption was satisfied for all four topics. Skewness and kurtosis statistics, as well as the Q-Q plot, suggested that normality was a reasonable assumption. Linearity of the dependent variable with the covariate was observed with scatterplots and examining the correlation between the two variables. The correlation was weak for all four topics. The covariates, familiarity of the base concept and familiarity of the target concept, were measured on a five-point Likert scale and were treated as continuous variables of the analyses. Homogeneity of regression slopes was confirmed by similar regression lines in the scatter plots of the dependent variable and covariates as well as the non-statistically significant interaction between explanation type and familiarity. The outcomes of these tests per topic and covariate are presented in the results section.

Table 14. Summary of base and target concepts by topic.

Topic	Base Concept	Target Concept
Frequency of extreme weather events	How steroid use effects baseball players	The increasing frequency of extreme weather events
Increasing rate of carbon dioxide	How water drains from a bathtub	The rate at which carbon dioxide (CO_2) is increasing in the atmosphere
Enhanced greenhouse effect	Additional blankets hold in more heat	The "greenhouse effect" (that is, how "greenhouse gases" keep the planet warm)
Weather, climate and climate change	The difference between a person's mood and their personality	Climate change is leading to changes in our weather and climate overtime

5.3 Results

To test the hypotheses posed in the introduction of this chapter, one-way ANOVAs and one-way ANCOVAs were conducted to determine if the mean change in understanding and if the mean change in belief certainty for each of the four topics (the frequency of extreme weather events; the rate at which carbon dioxide is increasing; the enhanced greenhouse effect; or weather, climate and climate change) differed based on the three different explanation types (science only, metaphor only, or science + metaphor) that were used for each topic. For all tests the assumption that the independent variable was made up of mutually exclusive groups was met as participants were randomly assigned to one of the three groups. A scatterplot of the residuals against the independent variable for each analysis presented here further confirmed the assumption of independence was met with a random display of points around 0. Multiple ANOVAs were conducted instead of a single MANOVA as each of the outcome variables were treated as conceptually independent. These multiple analyses were conducted with the purpose of retesting the hypotheses of the pilot study, and as noted above because the assumption of the homogeneity of variance was violated when involving all thirteen groups.

Analysis of variance in the change in understanding per topic

Frequency of extreme weather events

The assumption of normality was examined and met based on the review of skewness (.424) and kurtosis (.054) suggests the distribution of the dependent variable is approximately normal. The boxplot, Q-Q plot, and histogram also suggested normality was reasonable. According to Levene's test, the homogeneity of variance assumption was satisfied [$F(2, 330) = 2.532$, $p = .081$]. Upon examining the tests of between-subjects effects, it was observed that the one-way ANOVA is statistically significant, $F(2, 333) = 6.263$, $p = .002$ (Table 15). The effect size is small ($\eta^2 = .037$) and indicates about 3.7% of the variance of the change in understanding is attributable to the different explanation types. The observed power is quite strong, .894. The means and standard deviations of the change in understanding for each of the three explanation types for the topic of the frequency of extreme weather events were as follows: 1.58 (*SD* = 1.804) for science only; 1.03 (*SD* = 1.915) for metaphor only; and 1.94 (*SD* = 2.130) for science + metaphor. The means and profile plot (Figure 12A) suggest that the science + metaphor explanation produced the greatest change in understanding for the topic of frequency of extreme weather events, followed by the science only explanation and then the metaphor only explanation. Examining the multiple comparisons reveals which groups differed from each other. The Fischer's LSD test post-hoc test was used. This shows there is a significant difference between the science only and metaphor only explanations (p = .039), as well as the metaphor and science + metaphor explanations (p = .001). There was no significant difference between the science only and the science + metaphor explanations (p = .184), though on average the change in understanding for science + metaphor was higher than the science only explanation.

Increasing rate of carbon dioxide

The assumption of normality was examined and met based on the review of skewness (.050) and kurtosis (-.619) suggests the distribution of the dependent variable is approximately normal. The boxplot, Q-Q plot, and histogram also suggested normality was reasonable. According to Levene's test, the homogeneity of variance assumption was satisfied [$F(2, 351) = .601$, $p = .549$]. Upon examining the tests of between-subjects effects, it was observed that the one-way ANOVA is statistically significant, $F(2, 354) = 6.254$, $p = .002$ (Table 15). The effect size is small ($\eta^2 = .034$) and indicates about 3.4% of the variance of the change in understanding is attributable to the different explanation types. The observed power is quite strong, .894. The means and standard deviations of the change in understanding for each of the three explanation types for the topic concerning the increasing rate of carbon dioxide in the atmosphere were as follows: 1.23

(*SD* = 2.11) for science only; 2.08 (*SD* = 1.99) for metaphor only; and 2.06 (*SD* = 2.09) for science + metaphor. The means and profile plot (Figure 12B) suggest that the metaphor only explanation produced the greatest change in understanding of the increasing rate of carbon dioxide in the atmosphere, followed by the science + metaphor explanation and then the science only explanation. Examining the multiple comparisons shows which groups differed from each other. The Fischer's LSD test post-hoc test was used. This shows there is a significant difference between the science only and metaphor only explanations (p = .002), as well as the science only and science + metaphor explanations (p = .002). There was no significant difference between the metaphor only and the science + metaphor explanations (p = .963), though on average the change in understanding for metaphor only was slightly greater than the science + metaphor only explanation.

Enhanced greenhouse effect

The assumption of normality was examined and met based on the review of skewness (.313) and kurtosis (.218) suggests the distribution of the dependent variable is approximately normal. The boxplot, Q-Q plot, and histogram also suggested normality was reasonable. According to Levene's test, the homogeneity of variance assumption was satisfied [$F(2, 362) = .425$, $p = .654$]. Upon examining the tests of between-subjects effects, it was observed that the one-way ANOVA is not statistically significant, $F(2, 365) = 1.306$, $p = .272$ (Table 15). The means and standard deviations of the change in understanding for each of the three explanation types for the topic of the enhanced greenhouse effect were as follows: 1.34 (*SD* = 1.67) for science only; 1.59 (*SD* = 1.53) for metaphor only; and 1.65 (*SD* = 1.71) for science + metaphor. The means and profile plot (Figure 12C) suggest that the science + metaphor explanation produced the greatest change in understanding for the enhanced greenhouse effect, followed by the metaphor only explanation and then the science only explanation. Since there was no significant difference between the explanation types, the multiple comparisons table was not examined and post hoc tests were not completed.

Weather, climate and climate change

The assumption of normality was examined and met based on the review of skewness (.129) and kurtosis (.437) suggests the distribution of the dependent variable is approximately normal. The boxplot, Q-Q plot, and histogram also suggested normality was reasonable. According to Levene's test, the homogeneity of variance assumption was satisfied [$F(2, 353) = 2.228$, $p = .109$]. Upon examination of the tests of between-subjects effects, it was observed that the one-way ANOVA is statistically significant, $F(2, 356) = 1.648$, $p = .532$ (Table 15). The means and standard deviations of the change in understanding for each of the three explanation types for the topic concerning differences between weather, climate, and climate change were as follows: .949 (*SD* = 1.46) for science only; 1.04 (*SD* = 1.73) for metaphor only; and 1.19 (*SD* = 1.63) for science + metaphor. The means and profile plot (Figure 12D) suggest that the science + metaphor explanation produced the greatest change in understanding of differences between weather, climate, and climate change, followed by the metaphor only explanation and then the science only explanation. The multiple comparisons table was not examined because there was no significant difference between the explanation types, and no post hoc tests were conducted.

Table 15. Summary ANOVA table per topic (DV, change in understanding; IV, explanation type).

Topic	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	η^2	*Observed Power*
Frequency of extreme weather events	47.954	2, 333	24.00	6.36	.002	.037	.894
Increasing rate of carbon dioxide	53.226	2, 354	26.31	6.25	.002	.034	.894
Enhanced greenhouse effect	7.002	2, 365	3.05	1.31	.272	.007	.282
Weather, climate and climate change	3.297	2, 356	1.65	.633	.532	.004	.156

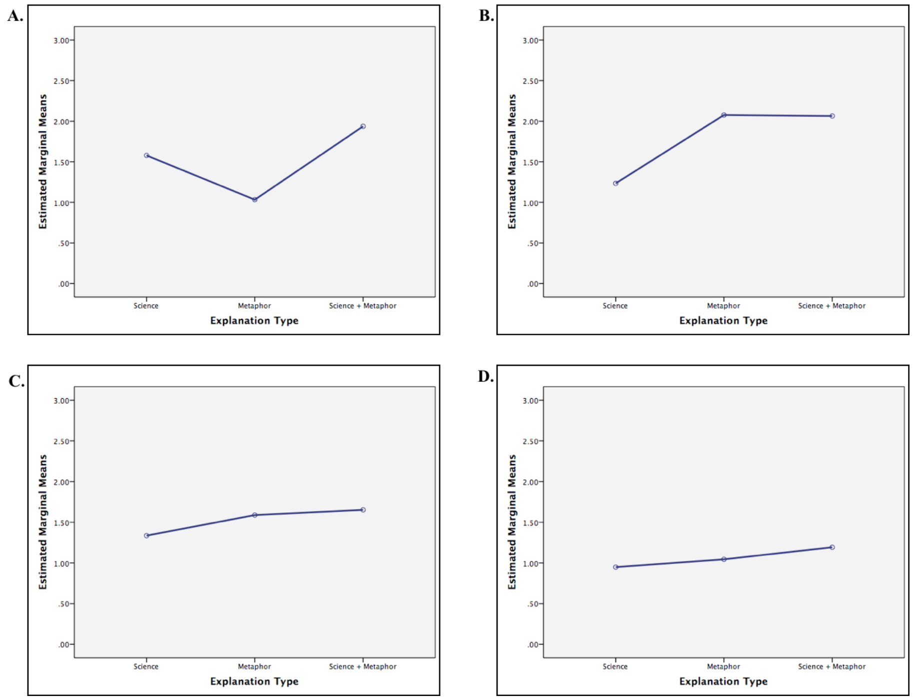


Figure 12. Profile plots per topic (DV, change in understanding).
A) the frequency of extreme weather events; B) the rate at which carbon dioxide is increasing; C) the enhanced greenhouse effect; and D) weather, climate and climate change.

Analysis of variance in the change in belief certainty per topic

Frequency of extreme weather events

In observing skewness (.896) and kurtosis (9.186), as well as the boxplot, Q-Q plot, and histogram, normality was reasonably assumed. According to Levene's test, the homogeneity of variance assumption was satisfied [$F(3, 444) = 1.976$, $p = .117$]. The effect size is small ($\eta^2 = .020$) and indicates about 2% of the variance in the change in belief certainty is attributable to the different explanation types. The observed power is strong, .713. Upon examining the tests of between-subjects effects, it was observed that the one-way ANOVA is statistically significant, $F(3, 444) = 3.04$, $p = .029$ (Table 16). The means and standard deviations of the change in belief certainty for the comparison group and each of the three explanation types for the topic of the frequency of extreme weather events were as follows: -.913 (SD = .981) for the comparison group; .039 (*SD* = .767) for science only; .141 (*SD* = 1.150) for metaphor only; and .182 (*SD* = 1.35) for science + metaphor. The means and profile plot (Figure 13A) suggest that the science + metaphor explanation produced the greatest change in belief certainty of the frequency of extreme weather events, followed by the metaphor only explanation, science only explanation and then the comparison group essay. The Fischer's LSD test post-hoc test was used to examine the differences between the groups. This shows there is a significant difference between the comparison group message and both the metaphor only and science + metaphor explanations (p = .013, p = .007, respectively). There was no significant difference however between the comparison group and the science only explanation as well as between each of the three explanation types (p > .05) despite the observed pattern in the means displayed in Figure 13A.

Increasing rate of carbon dioxide

In addition to skewness (.501) and kurtosis (13.969), the boxplot, Q-Q plot, and histogram were also examined to test normality. Based on these observations, it was determined that the assumption of normality was reasonable. According to Levene's test, the homogeneity of variance assumption was satisfied [$F(3, 465) = 3.173$, $p = .062$]. Upon examining the tests of between-subjects effects, it was observed that the one-way ANOVA was statistically significant, $F(3, 465) = 4.601$, $p = .003$ (Table 16). The effect size was small ($\eta^2 = .029$) and indicates about 2.9% of the variance in the change in belief certainty is attributable to the different explanation types. The observed power is quite strong, .889. The means and standard deviations of the change in belief certainty for the comparison group and each of the three explanation types for the topic pertaining to the increasing rate of carbon dioxide were as follows: -.191 (*SD* = .981) for the comparison group; .180 (*SD* = .753) for science only; .025 (*SD* = 1.03) for metaphor only; and .288 (*SD* = 1.33) for science + metaphor. The means and profile plot (Figure 13B) suggest that the science + metaphor explanation produced the greatest change in belief certainty of the increasing rate of carbon dioxide, followed by the science only explanation, the metaphor only explanation, and the comparison group treatment. Examining the multiple comparisons shows which groups differed from each other. The Fischer's LSD test post-hoc test was used. This shows there is a significant difference between the comparison group and science only essay (p = .008), the comparison group and the science + metaphor essay (p = .000), and the metaphor only and the science + metaphor (p = .049). There was no significant difference between the comparison group and the metaphor treatments (p = .117); the science only and the metaphor only (p = .267); and the science only and the science + metaphor (p = .433).

Enhanced greenhouse effect

To assess normality, skewness (1.055), kurtosis (10.650), the boxplot, the Q-Q plot, and the histogram were observed for the dependent variable and suggest normality was reasonable. According to Levene's test, the homogeneity of variance assumption was also satisfied [$F(3, 476) = .340$, $p = .796$]. Upon examining the tests of between-subjects effects, it was observed that the one-way ANOVA is statistically significant, $F(3, 476) = 3.021$, $p = .019$ (Table 16). The effect size is small ($\eta^2 = .019$) and indicates about 1.9%

of the variance in the change in belief certainty is attributable to the different explanation types. The observed power is strong, .711. The means and standard deviations of the change in belief certainty for the comparison group and each of the three explanation types for the topic of the enhanced greenhouse effect were as follows: -.191 (*SD* = .981) for the comparison group; .115 (*SD* = .982) for science only; .050 (*SD* = .964) for metaphor only; and .165 (*SD* = .991) for science + metaphor. The means and profile plot (Figure 13C) suggest that the science + metaphor explanation produced the greatest change in belief certainty of the enhanced greenhouse effect, followed by the metaphor only explanation, the science only explanation, and then the comparison group treatment. The Fischer's LSD test post-hoc test was used to examine the differences between the treatment groups. This shows there is a significant difference between the comparison group and two of the three explanation types (science, $p = .015$; science + metaphor, $p = .006$). There was no significant difference between the comparison group and metaphor explanation ($p = .060$); the science and metaphor explanations ($p = .606$); the science and science + metaphor explanations ($p = .686$); and the metaphor and science + metaphor explanations ($p = .371$).

Weather, climate and climate change

The assumption of normality was examined and met based on the review of skewness (-.210) and kurtosis (8.567), as well as the boxplot, Q-Q plot, and histogram, which suggests the distribution of the dependent variable is approximately normal. According to Levene's test, the homogeneity of variance assumption was satisfied [$F(3, 467) = .587$, $p = .624$]. Upon examining the tests of between-subjects effects, it was observed that the one-way ANOVA is statistically significant, $F(3, 467) = 2.618$, $p = .049$ (Table 16). The effect size is small ($\eta^2 = .017$) and indicates about 1.7% of the variance in the change in belief certainty is attributable to the different explanation types. The observed power is moderate, .641. The means and standard deviations of the change in belief certainty for the comparison group and each of the three explanation types for the topic of weather, climate and climate change were as follows: -.191 (*SD* = .981) for the comparison group; .103 (*SD* = 1.05) for science only; -.0296 (*SD* = .985) for metaphor only; and .164 (*SD* = 1.12) for science + metaphor. The means and profile plot (Figure 13D) suggest that the science + metaphor explanation produced the greatest change in belief certainty of the weather, climate and climate change topic, followed by the science only explanation, the metaphor only explanation, and then the comparison group treatment. The Fischer's LSD test post-hoc test was used to determine if there were significant differences between the treatment groups. This shows there is a significant difference between the comparison group and science only ($p = .030$) as well as the science + metaphor explanation ($p = .011$). There were no significant differences between the comparison group and metaphor only explanation, as well as between the three other explanations despite the pattern observed in the profile plot ($p > .05$).

Table 16. Summary ANOVA table per topic (DV, change in belief certainty; IV, explanation type).

Topic	*Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	η^2	*Observed Power*
Frequency of extreme weather events	9.585	3, 444	3.20	3.04	.029	.020	.713
Increasing rate of carbon dioxide	15.338	3, 465	5.11	4.60	.003	.029	.889
Enhanced greenhouse effect	8.693	3, 476	2.90	3.02	.029	.019	.711
Weather, climate and climate change	8.318	3, 467	2.77	2.62	.049	.017	.649

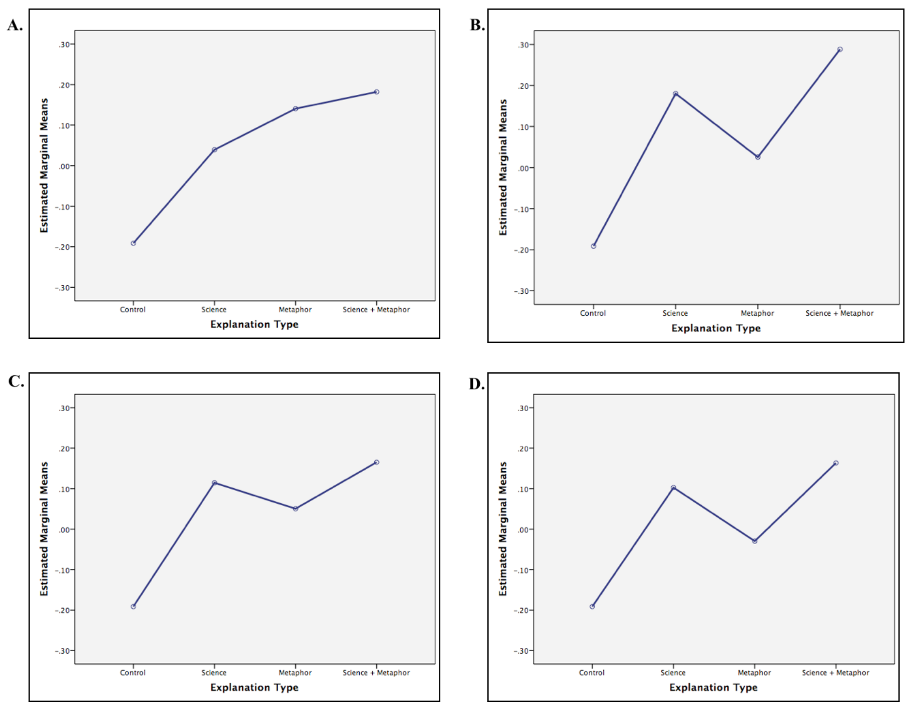


Figure 13. Profile plots per topic (DV, change in belief certainty).
A) the frequency of extreme weather events; B) the rate at which carbon dioxide is increasing; C) the enhanced greenhouse effect; and D) weather, climate and climate change.

Analysis of covariance in the change in understanding and conceptual familiarity per topic

The assumptions that the independent variable (explanation type) was made up of mutually exclusive groups and the dependent variable (change in understanding) follows a normal distribution were previously examined for the ANOVA analyses above, and were met. The assumption that the covariate is a continuous variable was also met, as base concept and target concept familiarity were measured on a 5-point Likert scale, and treated as a continuous variable for the purposes of the ANCOVAs. The assumptions of homogeneity of variance, linearity, and homogeneity of regression slopes are each examined and confirmed per topic below.

Frequency of extreme weather events

According to Levene's test, the homogeneity of variance assumption was satisfied for each analysis of covariance [base: $F(2, 330) = 3.014$, $p = .051$; target: $F(2, 330) = 2.222$, $p = .110$]. Linearity of the dependent variable with the covariate was examined with scatterplots and overall the change in understanding and familiarity of the base concept and the familiarity of the target concept suggested negative relationships. Homogeneity of regression slopes was confirmed by the non-statistically significant interaction of base familiarity [$F(3, 327) = 1.256$, $p = .286$] and target familiarity [$F(3, 327) = .379$, $p = .685$] by explanation type.

The results of the ANCOVA suggest a non-significant effect for explanation type ($F = 2.386$, $df = 2, 327$, p = .094), when controlling for base familiarity (Table 17). Table 18 shows that when controlling for target familiarity, explanation type is also not significant ($F = 1.807$, $df = 2, 327$, p = .116). When controlling for base familiarity, the adjusted means for all explanation types increased slightly. However, when controlling for target familiarity, the adjusted means remained the same as the observed means for each explanation type. While there was no significant difference between the explanation types ($p > .05$), the observed and adjusted means, as well as the profile plots, demonstrate that the pattern of the change in understanding is the same as the ANOVA analysis about: science + metaphor explanation had the greatest change in understanding, followed by the science only and then metaphor only explanations for the frequency of extreme weather events topic.

Table 17. ANCOVA results and descriptive statistics for change in understanding by explanation type (covariate = base familiarity).

Topic for this analysis was the frequency of extreme weather.

Explanation Type	Change in Understanding			
	Observed Mean	Adjusted Mean	SD	n
Science	1.58	1.60	1.80	102
Metaphor	1.03	1.03	1.91	121
Science + Metaphor	1.94	1.93	2.13	110
Source	SS	df	MS	F
Explanation Type	18.101	2	9.050	2.386
Error	1240.29	327	3.793	

Note. $R^2 = .054$, Adj. $R^2 = .040$, adjustments based on base familiarity mean = 3.27. Homogeneity of regression tested and not significant: $F = 2.022$, $p > .05$.

Table 18. ANCOVA results and descriptive statistics for change in understanding by explanation type (covariate = target familiarity).

Topic for this analysis was the frequency of extreme weather.

Explanation Type	Change in Understanding			
	Observed Mean	Adjusted Mean	SD	n
Science	1.58	1.58	1.80	102
Metaphor	1.03	1.03	1.91	121
Science + Metaphor	1.94	1.94	2.13	110
Source	SS	df	MS	F
Explanation Type	13.740	2	6.870	1.807
Error	1243.249	327	3.802	

Note. $R^2 = .052$, Adj. $R^2 = .037$, adjustments based on base familiarity mean = 3.48. Homogeneity of regression tested and not significant: F = 1.757, p > .05.

Increasing rate of carbon dioxide

According to Levene's test, the homogeneity of variance assumption was satisfied for each analysis of covariance [base: $F(2, 351) = 0.414$, $p =$; target: $F(2, 351) = 0.822$, $p = .441$]. Linearity of the dependent variable with the covariate was examined with scatterplots and overall the change in understanding and familiarity of the base concept and the familiarity of the target concept suggested negative relationships. Homogeneity of regression slopes was confirmed by the non-statistically significant interaction of base familiarity [$F(3, 348) = 1.422$, $p = .236$] and target familiarity [$F(3, 348) = 6.147$, $p = .254$] by explanation type.

The results of the ANCOVA suggest a non-significant effect for explanation type ($F = .830$, $df = 2, 248$, $p = 0.437$), when controlling for base familiarity (Table 19). Table 20 shows that when controlling for target familiarity, explanation type is also not significant (F=0.590, $df = 2, 348$, $p = .555$). When controlling for base familiarity, the adjusted means remained the same for all explanation types. However, when controlling for target familiarity, the adjusted mean was unchanged for the science only explanation, while the metaphor only mean increased and the science + metaphor slightly increased. Despite these changes, there was no significant difference ($p > .05$) between the explanation types when controlling for each base and target familiarity. For both the observed and adjusted means, as well as the profile plots, the change in understanding for the topic of increasing rate of carbon dioxide was the greatest for the metaphor only explanation followed by the science + metaphor explanation and science only explanation.

Table 19. ANCOVA results and descriptive statistics for change in understanding by explanation type (covariate = base familiarity).

Topic for this analysis was increasing rate of carbon dioxide.

Explanation Type	*Change in Understanding*			
	Observed Mean	*Adjusted Mean*	*SD*	*n*
Science	1.23	1.23	2.11	111
Metaphor	2.08	2.08	1.99	118
Science + Metaphor	2.06	2.06	2.09	125
Source	*SS*	*df*	*MS*	*F*
Explanation Type	7.039	2	3.520	.830
Error	1475.625	348	4.240	

Note. $R^2 = .046$, Adj. $R^2 = .032$, adjustments based on base familiarity mean = 3.91. Homogeneity of regression tested and not significant: $F = 1.422$, $p > .05$.

Table 20. ANCOVA results and descriptive statistics for change in understanding by explanation type (covariate = target familiarity).

Topic for this analysis was increasing rate of carbon dioxide.

Explanation Type	*Change in Understanding*			
	Observed Mean	*Adjusted Mean*	*SD*	*n*
Science	1.23	1.23	2.11	111
Metaphor	2.08	2.11	1.99	118
Science + Metaphor	2.06	2.04	2.09	125
Source	*SS*	*df*	*MS*	*F*
Explanation Type	4.811	2	2.406	.590
Error	1418.547	348	4.076	

Note. $R^2 = .083$, Adj. $R^2 = .070$, adjustments based on base familiarity mean = 2.77
Homogeneity of regression tested and not significant: $F = 6.147$, $p > .254$.

Enhanced greenhouse effect

According to Levene's test, the homogeneity of variance assumption was satisfied for each analysis of covariance [base: $F(2, 363) = 0.390$, $p = .677$; target: $F(2, 363) = 0.434$, $p = .648$]. Linearity of the dependent variable with the covariate was examined with scatterplots and overall the change in understanding and familiarity of the base concept and the familiarity of the target concept suggested a positive and a negative relationship, respectively. Homogeneity of regression slopes was confirmed by the non-statistically significant interaction of base familiarity [$F(3, 359) = 0.386$, $p = .763$] and target familiarity [$F(3, 359) = 0.614$, $p = .606$] by explanation type.

The results of the ANCOVA suggest a non-significant effect for explanation type ($F = 0.563$, $df = 2, 359$, $p = .570$), when controlling for base familiarity (Table 21). Table 22 shows that when controlling for target familiarity, explanation type is also not significant ($F = 0.208$, $df = 2, 359$, $p = .813$). When controlling for base familiarity, the adjusted means were the same as the observed means. However, when controlling for target familiarity, the adjusted mean for the metaphor only explanation was the same as the observed mean, the science only adjusted mean was greater than the observed mean, and the science + metaphor mean decreased slightly. While there was no significant difference ($p > .05$) between the explanation types, the observed and adjusted means demonstrate the same pattern for the change in understanding for the topic of the enhanced greenhouse effect when controlling for base familiarity as well as target familiarity: science + metaphor explanation had the greatest change in understanding, followed by the metaphor only and then science only explanations.

Table 21. ANCOVA results and descriptive statistics for change in understanding by explanation type (covariate = base familiarity).

Topic for this analysis was enhanced greenhouse effect.

Explanation Type	*Change in Understanding*			
	Observed Mean	*Adjusted Mean*	*SD*	*n*
Science	1.34	1.34	1.67	131
Metaphor	1.59	1.59	1.53	119
Science + Metaphor	1.65	1.65	1.71	115
Source	*SS*	*df*	*MS*	*F*
Explanation Type	3.035	2	1.517	.563
Error	967.012	359	2.694	

Note. $R^2 = 0.10$, Adj. $R^2 = -.003$, adjustments based on base familiarity mean = 3.86. Homogeneity of regression tested and not significant: $F = .386$, $p > .05$.

Table 22. ANCOVA results and descriptive statistics for change in understanding by explanation type (covariate = target familiarity).
Topic for this analysis was enhanced greenhouse effect.

Explanation Type	*Change in Understanding*			
	Observed Mean	*Adjusted Mean*	*SD*	*n*
Science	1.34	1.35	1.67	131
Metaphor	1.59	1.59	1.53	119
Science + Metaphor	1.65	1.63	1.71	115
Source	*SS*	*df*	*MS*	*F*
Explanation Type	1.116	2	.558	.208
Error	965.182	359	2.689	

Note. $R^2 = .012$, Adj. $R^2 = -.002$, adjustments based on base familiarity mean = 3.05. Homogeneity of regression tested and not significant: $F = .614$, $p > .05$.

Weather, climate and climate change

According to Levene's test, the homogeneity of variance assumption was satisfied for each analysis of covariance [base: $F(2, 253) = 2.374$, $p = .095$; target: $F(2, 253) = 1.820$, $p = .164$]. Linearity of the dependent variable with the covariate was examined with scatterplots and overall the change in understanding and familiarity of the base concept and the familiarity of the target concept suggested both a positive and a negative relationship, respectively. Homogeneity of regression slopes was confirmed by the non-statistically significant interaction of base familiarity [$F(3, 350) = 1.235$, $p = .297$] and target familiarity [$F(3, 350) = 1.747$, $p = .572$] by explanation type.

The results of the ANCOVA suggest a non-significant effect for explanation type ($F = 1.009$, $df = 2, 350$, $p = .365$), when controlling for base familiarity (Table 23). Table 24 shows that when controlling for target familiarity, explanation type is also not significant ($F = 0.099$, $df = 2, 350$, $p = .906$). When controlling for base familiarity, adjusted means were higher than the observed mean for the science only and metaphor only explanations, and lower for the science + metaphor explanation. The adjusted mean for the science only explanation was higher than the observed mean when controlling for target familiarity; however, the metaphor only and science + metaphor adjusted means remained the same as the observed mean when target familiarity was controlled for. The observed and adjusted means when controlling for base and target familiarity show the same pattern with the science + metaphor explanation having the greatest change in understanding for the topic of weather, climate and climate change followed by the metaphor only explanation and science only explanation. However, there was no significant difference ($p > .05$) between the explanation types.

Table 23. ANCOVA results and descriptive statistics for change in understanding by explanation type (covariate = base familiarity).

Topic for this analysis was weather, climate and climate change.

Explanation Type	*Change in Understanding*			
	Observed Mean	*Adjusted Mean*	*SD*	*n*
Science	.949	.955	1.46	117
Metaphor	1.04	1.05	1.73	135
Science + Metaphor	1.19	1.17	1.63	104
Source	*SS*	*df*	*MS*	*F*
Explanation Type	5.249	2	2.624	1.01
Error	909.946	350	2.600	

Note. $R^2 = .014$, Adj. $R^2 = .000$, adjustments based on base familiarity mean = 3.74. Homogeneity of regression tested and not significant: $F = 1.235$, $p > .05$.

Table 24. ANCOVA results and descriptive statistics for change in understanding by explanation type (covariate = target familiarity).

Topic for this analysis was weather, climate and climate change.

Explanation Type	*Change in Understanding*			
	Observed Mean	*Adjusted Mean*	*SD*	*n*
Science	.949	.952	1.46	117
Metaphor	1.04	1.04	1.73	135
Science + Metaphor	1.19	1.19	1.63	104
Source	*SS*	*df*	*MS*	*F*
Explanation Type	.516	2	.258	.099
Error	914.337	350	.669	

Note. R^2 = .009, Adj. R^2 = -.005, adjustments based on base familiarity mean = 3.52. Homogeneity of regression tested and not significant: $F = .669$, $p > .05$.

5.2 Discussion and Conclusion

For some climate change concepts, using metaphors to explain climate change can benefit an individual's understanding. When controlling for familiarity of the base and target concepts of a metaphor prior to reading an explanation of a specific topic, the explanation type itself is not significant when examining the resultant change in understanding. However, providing a well-articulated explanation, whether it is strictly a science explanation, metaphor only explanation, or a combination of the two, influences an individual's understanding and belief certainty that climate change is happening – in comparison to being exposed to an unrelated topic. While often there were no significant differences between explanation types there were notable trends in both the mean changes in understanding and belief certainty for all four topics. These trends will be discussed in the following sections.

Significant and non-significant changes in understanding of climate change concepts

The change in understanding was examined for four climate change concepts, each explained three different ways. The understanding of 'how global warming works' has been demonstrated to improve after exposure to a scientific, mechanistic explanation of the greenhouse effect (Ranney & Clark, 2016; Ranney et al., 2012). Additionally, metaphorical explanations of scientific concepts in general have been shown to improve understanding of the target concept (Glynn & Takahashi, 1998; Guerra-Ramos, 2011). However, other studies have found that metaphors were unsuccessful at improving or resulted in non-significant changes in understanding (Galesic & Garcia-Retamero, 2013; Mason, 1994). Similarly the study presented herein exhibits mixed results. In particular three different identifiable patterns emerged: one for the frequency of extreme weather events; another for the increasing rate of carbon dioxide; and a third shared by the enhanced greenhouse effect, and weather, climate and climate change essays.

Before discussing the results further, it is important to note that there are two limitations to the analyses, which were performed to answer *H1*. The first limitation is that there is no comparison to a comparison group. No comparisons were made with the comparison group's change in understanding because participants who were randomly assigned to the comparison group essay were not asked to explain a climate change concept in the post-test as it was assumed there would be no change in their understanding score. Thus, there was no change in the understanding score calculated for this group. The second limitation is due to unequal variances for all message treatment groups, the four topics explained in the three different ways were not compared and therefore the results cannot be generalized for explaining climate change. Instead, the results are specific to a climate change concept and may not apply to other specific climate change concepts (i.e. explaining sea level rise). Despite the limitations, it is still possible to derive meaningful insight from the perspective of individual concepts and to explore ways to improve on future study design, which strives to eliminate or minimize the variation across the many treatment groups and potentially allow for a more generalizable set of results.

For the groups exposed to explanations about the frequency of extreme weather events, the greatest change in understanding resulted from the exposure to the science + metaphor explanation, followed by the science only and metaphor only explanations (S+M > S > M). However, there were only significant differences between the science only and metaphor only explanations, and the science + metaphor and metaphor only explanations; there was no significant difference between the science only and science + metaphor explanations. Each explanation type, on average, did produce a positive change score, which indicates an improvement in understanding. For this particular topic, these results imply that the scientific explanation component was an important piece of the explanation in comparison to the metaphor component. When the scientific explanation component was part of the essay, not only was the change in understanding greater, it was also significantly different from an essay, which included the metaphor explanation component. This is a unique and unexpected result because incorporating a metaphor into an explanation was expected to result in a greater increase in a participant's understanding than a scientific explanation alone. The understanding of a target concept is enhanced through a high familiarity with the associated base concept (Bettman & Park, 1980; Feiereisen et al., 2008). One reasonable explanation for this result is that there was an overall lower familiarity with the associated base concept thus impacting the usefulness of the selected metaphor. However, familiarity of the base on average was moderate. Another possibility is that credibility or acceptance of the base concept impacted the outcome. Although metaphors have been shown to increase the perception of a communicator's credibility (Sopory & Dillard, 2002), the credibility of the science explanation may also have been reduced with the use of the baseball player on steroids metaphor, and may have affected the participants' understanding of the target concept. A few (3 out of 30) individuals during the non-expert interviews (Study 2) took issue with the baseball player on steroids metaphor, commenting it was a bad metaphor because it wasn't true or steroids didn't work in the exact way the essay described. The metaphor was not altered for this experiment because most non-experts liked the metaphor and found it useful, but the more negative viewpoint of the metaphor could be more widespread than the interviews suggest. However, the relationship to credibility is speculative and further investigation especially for this topic of the frequency of extreme weather events is necessary due to the unexpected pattern in the change in understanding observed.

A different pattern in the change in understanding arose for explaining the increasing rate of carbon dioxide. For this topic, participants who read the metaphor only essay had the greatest change in understanding, followed by the science + metaphor explanation group, and then the science only explanation group (M > S+M > S). There were significant differences found between the metaphor only and science only explanations, and the science + metaphor and science explanations. While the change in understanding was higher for the metaphor only group than for the science + metaphor group, there was no significant difference between the two. It is also important to note that for each explanation type on average there was a positive change score, which indicates an improvement in understanding. The metaphor is the important component for this particular set of explanatory essays. In the case of explaining the increasing rate of carbon dioxide, it is evident that an explanation incorporating a metaphor results in a greater and significant change in understanding than a scientific explanation alone. A possible reason for the metaphor component having resulted in such an effect is because the topic covering the increasing rate of carbon dioxide is ostensibly classified as a highly complex concept. The higher complexity of this topic requires more analytical information processing, such as understanding rates and the effects of changing rates, which are mathematical in nature (Guy et al., 2013; Schön, 1993).

The third pattern in the change in understanding which emerged when both the enhanced greenhouse effect, and weather, climate and climate change were presented was: the science + metaphor explanation had the greatest change in understanding, followed by the metaphor only explanation, and then the science only explanation (S+M > M > S). While on average the change in understanding was numerically different and increased from pre to post-test irrespective of explanation type, the change in understanding mean differences were not statistically significantly different. For all three of the explanation types for these two topics the change in understanding was positive (post-test score minus pre-test score) and indicates understanding scores increased or improved. A potential reason for the non-significant difference in the three explanation types is: both of these topics could be classified as topics that are low in complexity. This means they require a more experiential or visual understanding, and are topics that have schemas or mental models that more quickly come to mind. Higher complexity concepts require more detailed explanations and employ lower complexity concepts to do so (i.e. the base concept of a metaphor). On the other hand, low complexity concepts are already easier to process and therefore do not benefit from being explained using additional concepts (Schön, 1993).

Controlling for base and target concept familiarity

The analyses presented in this chapter also examined both base concept familiarity and target concept familiarity as covariates in order to control for effects conceptual familiarity has on understanding. Incorporating base and target familiarity into the analyses as covariates addressed *H3a* and *H3b*. Including familiarity as a covariate allowed for a clearer picture of whether the change in understanding from pre- to post-test was due to the explanation type or due to how familiar participants were with the base and target concepts at the onset of the survey experiment.

Familiarity with the base concept of a metaphor is particularly important because if familiarity of the base concept – the concept that is assumed by the communicator to be well-known by the audience – is in fact not familiar or understood, the understanding of the target concept – the concept the communicator wants the audience to learn or know more about – diminishes (Gentner & Markman, 1997; Guerra-Ramos, 2011). Sopory and

Dillard (2002) demonstrated through a meta-analysis the importance of familiarity of base and target concepts of a metaphor. The trend was that metaphors in comparison to literal language were beneficial for understanding and persuasion when individuals were more highly familiar with the base and metaphor concepts. Similarly, there was no significant difference in the mean change in understanding between the three explanation types when controlling either for base familiarity or target familiarity for each of the four topics. However, the present study, the patterns observed in the change in understanding for each topic was consistent: frequency of extreme weather events, SM > S > M; increasing rate of carbon dioxide, M > SM > S; enhanced greenhouse effect, SM > M > S; and weather, climate and climate change, SM > M > S. One reason for the non-significant difference between the explanation types, while the same patterns exist when controlling for base and target familiarity, is that participants on average were moderately familiar with the base and target concepts. Familiarity of the base concept and target concept is not affecting the outcome because participants in the sample began at the same approximate level of familiarity. The significant differences observed when not controlling for familiarity were not biased because of the little difference in the initially self-reported familiarity with the base or target concepts of the essays.

Significant and non-significant changes in belief certainty of climate change

To address *H2*, the change in belief certainty was also examined for the same four climate change concepts that were explained in three different ways, and were also compared to the comparison group message condition. In addition to improving individuals' understanding of how global warming works, the previously mentioned mechanistic explanation also increased individuals' climate change acceptance (Ranney & Clark, 2016). Metaphors have been used as a persuasion technique with the purpose of influencing attitudes (Dryzek & Lo, 2015; Sopory & Dillard, 2002). This study examined the effects on belief certainty that climate change is happening when using metaphors as an alternative or additional option for explaining how global warming works, as well as three other climate change concepts. The science + metaphor explanation consistently had the greatest change in belief certainty for all four topics, while unsurprisingly the comparison essay group had the least change in belief certainty. In terms of the effectiveness in changing belief certainty level when explaining the frequency of extreme weather events topic, the metaphor only explanation followed the science + metaphor explanation, and then the science only explanation (S+M > M > S). For the other three topics, the trend was the opposite: the science only explanation followed the science + metaphor explanation, and then the metaphor only explanation (S+M > S > M).

Since the ANOVAs were run separately for each topic due to the unequal variances across all thirteen groups, the results cannot necessarily be generalized to other climate change topics or climate change more broadly. It is also important to note that the sample as a whole was more certain that global warming is happening at the onset of study than a representative sample of the United States population. About two-thirds of the sample was at least 'very sure' that global warming is happening. Due to the high levels of belief certainty it was unlikely for participants to increase their belief certainty, which strongly suggests the existence of a ceiling effect. However, there was a small upward movement and some similarities in trends observed across topics in how the explanation types influenced the change in belief certainty. While there was a statistically significant difference between the explanation type groups within each of the four topics, the only specific differences between groups were found between an explanation type and the comparison group. In the case of the frequency of the extreme weather events topic, the change in belief certainty was significantly greater for the metaphor only and the science + metaphor explanations in comparison to the comparison group. The change in belief certainty was also significantly greater for the science and the science + metaphor explanations in comparison to the comparison group for the other three topics – the increasing rate of carbon dioxide; the enhanced greenhouse effect; and weather, climate and climate change. These changes in belief certainty were positive for all explanation types indicating that participants' belief certainty improved from the pre- to post-test. The results demonstrate that the science + metaphor is the most effective of the explanation types for the topics in comparison to the comparison group, but not significantly different from the metaphor only or science only explanations for each of the four topics. Overall, the results lead to the conclusion that some type of explanation or combination thereof (science, metaphor or science + metaphor) can influence an individual's belief certainty positively.

These results are also particularly interesting for the enhanced greenhouse effect topic because the science explanation was the "how global warming works" (slightly modified) essay used by Ranney and Clark (2016). The mechanistic explanation of the greenhouse effect was also paired with the blanket metaphor for the science + metaphor explanation. There was no significant difference, as stated previously, between the three explanation types. However, the results indicate that the change in belief certainty was slightly higher for the science + metaphor explanation than the science only (mechanistic) explanation, which suggests that the metaphor enhanced the explanation. This difference in the mean change in belief certainty between the two explanation types however was very small – the difference was .050.

Summary

The results of the experiment did not conclusively demonstrate that metaphors consistently nor significantly improve knowledge for four distinct climate change concepts, or belief certainty that climate change is occurring. All explanatory essays improved understanding and increased belief certainty. Understanding scores from pre- to post-test were statistically significantly different. Specifically for three of the four concepts, the combination essay (science + metaphor) had the greatest change in understanding. However, there were no significant differences between explanation types when controlling for base and target familiarity due to the moderate levels of familiarity on average for those concepts. Although not statistically significant, the pattern of findings do suggest that metaphor, especially when provided along with a scientific explanation, may enhance understanding of some climate concepts. This experiment further emphasizes that the usage of metaphors results in mixed outcomes, as demonstrated through other investigations of the effectiveness of metaphor.

CHAPTER 6. GENERAL DISCUSSION

6.1 Learning from Expert and Non-Expert Interviews

The expert and non-expert interview studies each had separate but also related objectives. Subjecting the four short ‘science + metaphor’ essays through a technical expert review ensured that the scientific content was accurate, and that the science and metaphor pairings were both accurate and practical. Interviewing climate science experts also allowed these specialists to share some of their experiences using (or choosing not to use) metaphors with lay audiences and to discuss how they similarly or differently might go about explaining climate change to various lay audiences with the provided short essays as a baseline for the discussions. The non-expert interviews were aimed at exploring the effectiveness and responses to researcher-developed metaphors. More specifically these interviews were designed to understand what non-experts grasped about climate change before reading the essays, record reactions to each of the essays, and determine what individuals found helpful from the passage through direct statements and then inferring what was helpful to their understanding through re-explaining the concepts in their own words after reading the passages.

Interviewing both experts and non-experts was important because they together expounded upon the knowledge and usability gap when it comes to climate change information and its effective communication. Also in combination the qualitative studies demonstrated there was an overall agreement that metaphors were uniquely useful tools for each group. It is fairly well known that scientists and non-scientists often perceive the usefulness of scientific information differently. This is in part due to each group being charged with different roles, and having different concerns, purposes, languages, norms and temporal needs (Blockstein, 2002; Dabelko, 2005; Guston, 2001; S. S. Jasanoff, 1986; National Research Council, 2009). Scientists are trained to use a rigorous form of communication that is efficient and effective in the realm of science, but is neither of those things outside the realm of science. Communicating high level, complex scientific findings to outside audiences is a challenge as the level of detail and domain specific terminology especially can almost appear to be a foreign language which in turn obscures and drowns out the key messages that scientists hope to convey (Somerville & Hassol, 2011). Some of this information that is conveyed is of importance though, however just sharing it via the deficit model even in simpler, shorter sound bites does not resonate with non-scientific audiences.

The experts interviewed in the first study recognized the challenges they face in communicating climate change and saw value in using other explanatory techniques, including metaphor. In fact, several experts expressed some internal struggles with what phrases to use and how to explain rather complex and critical concepts related to climate change. It was particularly interesting and useful to hear their opinions and thought processes when deciding to use certain words or phrases because they are so commonly used and familiar to lay audiences, yet they are not perfectly scientifically accurate. A common theme encountered in the expert interviews was the conundrum of whether it was okay to use a particular phrase or not mostly in regards to the scientific understanding of the related phenomena. For example, a particularly detailed discussion as to why the phrase "heat trapping" was incorrect typically led to an in-depth discourse of the physics required to accurately relate what gases actually do in the atmosphere. Ultimately though, such detail was acknowledged as an issue and while the experts may cringe at the phrase they admit what matters is that non-scientists understand the gist and bigger picture. Drawing such conclusions has led them to focus their communication techniques when interacting with non-expert audiences on incorporating visuals, personal experiences, and explanatory metaphors.

Overall, the experts were enthusiastic and reacted positively to the essays and the metaphors. In their scientific nature they were also critical and objective when providing their input on the metaphors reviewed. The experts addressed the need to not only maintain accuracy and credibility of the science but also the importance of carefully crafting and using well-matched and accurate metaphors. The concerns about using metaphors are well founded because if they are not accurate and adequately explained, metaphors do pose a danger to backfiring and communicate the wrong ideas to others (Guerra-Ramos, 2011). Experts also identified that such downfalls of metaphors can be avoided by tailoring explanations to the audience. For example, one expert discussed that they would use a different comparison for a garden club they might present to versus an insurance company when talking about extreme weather events. Through the interviews experts expressed what attracted them to the use of metaphors and that they could see the value of metaphors both as a tool to help them explain to others, and additionally saw metaphors as a way to connect with lay audiences in a way that help their audience understand and make sense of climate change as an issue.

Non-scientists on the other hand are also not blank slates; they have relevant knowledge and beliefs, some of which are likely based in their understanding of science that shape the mental models they use to interpret climate information communicated to them (Morgan et al., 2002). Individuals and groups require information to fit their needs, to be in line with or gradually expand their current knowledge, and flow in a communication fashion they are comfortable with. There are also other factors to consider and contribute to what lay audiences know and what influences their decisions including political factors, leadership directives, and other priorities that compete with scientific information (Dilling & Lemos, 2011; National Research Council, 2009).

Indeed non-experts interviewed were not blank slates and did have some knowledge of climate change and mental models in which they understood various relevant climate change concepts. While aware of the issue, there was a lack of clarity and lack of confidence in their conceptions of climate change. Additionally some common misconceptions such as the ozone layer being a result of or causing climate change (Bostrom et al., 1994; Leiserowitz & Smith, 2010; Niebert & Gropengiesser, 2012; Seacrest et al., 2000), and the equating of weather and climate (Bostrom et al., 1994; Reynolds et al., 2010; Elke U. Weber & Stern, 2011) were expressed. In the discussions centered on each of the four essays, there were numerous positive remarks regarding the metaphors including liking the comparison, as well as the clarity, relatability, and ability to visualize the metaphor to better understand the focal concept.

Despite the metaphors seldom being rearticulated when participants were asked to explain each climate change concept, there were some indicators that perhaps the metaphors were actually influential and not simply liked for one reason or another. The post-exposure explanations were more detailed, more confidently expressed, and misconceptions were eliminated.

Gathering insight from both experts and non-experts were critical to building well-informed short explanatory essays. Based on the evaluation from these groups, each essay's accuracy was improved and incorporated content that was more practical so that the messages were overall more ecologically valid based on what was learned from the experts. From the non-expert interviews new insight was augmented as to what makes metaphorical explanations of climate change clear versus unclear, helpful versus unhelpful, and understood versus confused. It was interesting to observe though that despite the differences in purpose of the two sets of interviews, experts and non-experts did come to the same conclusion: metaphors are useful. However, similar to science, metaphors are useful to experts and non-experts in different ways. The agreement though that metaphors are useful is promising. Such a communication technique is overall viewed favorably by each, and can create and foster an important connection between experts and non-experts.

6.2 Contrast between Non-Expert Interviews and Message Testing Experiment

Both qualitative studies were used to inform the revisions of the stimulus materials, which would subsequently be further examined in the message testing experiment. There are some notable observations that can be derived from comparisons between Study 2 and Study 3 since one set of interviews involved non-experts and presumably most, if not all, survey participants were non-experts as well. In this investigation, there were two distinct approaches, which examined non-experts' understanding of climate science concepts. The combination of these different methodologies show the potential effectiveness of metaphor usage in changing how climate change is discussed and narrowing the knowledge gap. The prospective usefulness of this approach is through first deliberately designing and then testing specifically constructed or optimized metaphors in a manner that is grounded in conceptual metaphor theory (Kendall-Taylor et al., 2013; Lindland & Kendall-Taylor, 2012; Volmert, 2014). One particular comparison that can be drawn between the two studies is from the pre- and post-explanations articulated by the participants. In both the interviews and the message testing survey, the understanding of the climate change concepts was low, while belief certainty was unexpectedly high. This was evident in the vague, or lack of details provided by the non-experts in the interviews, as well as a lack of confidence in what was known; and evident in the open-ended responses of the survey often including "I don't know" as the response, or the response including vague language and inaccuracies.

The post-essay exposure explanations of each study also exhibited a similar result: the metaphors were less frequently rearticulated even when the essay included a metaphor – the participants assigned to a science only essay in the message testing survey expectedly did not include any metaphor in their post-test explanation, so specifically this group's per topic post-test open-ended responses are not being referenced here. However, the interviews did allow for the following observation to be made: non-experts may not have used the metaphor in the explanations of the concepts later in the interviews, but they did acknowledge the metaphors' presence in the essay, and discussed the helpfulness of the metaphors. Particularly the metaphors were helpful to their reading and understanding of the content. These deeper discussions lend some support that the change in understanding observed in the quantitative study could be related to the influence of the metaphor. Thibodeau and Boroditsky (2013) came to a similar conclusion – albeit with different metaphors describing crime as a beast and crime as a virus. Participants in their experiment did not identify the metaphor as having a direct influence on their response to how a city should respond to crime, but the differences in the open-ended responses influenced how to grapple with crime as a beast – increasing enforcement – and dealing with crime as a virus – enacting proactive programs and measures.

A comparison between the changes in belief certainty between the two studies cannot be made because belief in the reality of climate change was not addressed at the end of the interviews. However, the trends observed in the results for each of the four topics, with belief certainty positively changing the most for the science + metaphor essay for three of the four topics, maybe have been an influence of the increase in understanding. The correlation between building knowledge and increasing acceptance of climate change has been demonstrated in other studies investigating both understanding and acceptance of climate change (Guy, Kashima, Walker, & O'Neill, 2014; Ranney & Clark, 2016; Ranney et al., 2012).

6.3 Implications for Theory

The series of studies that have been completed for this dissertation adds to the body of literature that seeks to explain the science of climate change in a clearer and more effective manner. Specifically, the sequential nature of these studies were arranged purposefully to build off of each other to first develop and optimize explanatory essays using metaphors which explain proven scientific concepts for lay audiences and then to subsequently evaluate the effects of such explanations on the understanding of the associated literal, scientifically-described concepts as well as the perception of the reality of climate change. The findings presented here are the practical outcomes of following a research model recommended by Morgan et al. (2002) in developing effective messages for non-experts. The six steps include: 1) review expert literature to develop messages, 2) validate the constructed expert model with technical experts, 3) examine non-expert mental models, 4) compare expert and non-expert mental models, 5) construct a single description for each concept(s), and 6) test messages developed based on the information gathered.

Following these aforementioned steps allowed for expert and non-expert understandings, thoughts, and communication preferences to be considered in the development of the final stimulus materials that were tested in the third study. This methodology employed a process for continuous evaluation of developed explanatory essays. By the time the short essays were used in the message testing experiment, the essays had been revised three times: once after the pilot study, second after they were reviewed by experts, and a third time after the non-expert interviews. This process demonstrated the importance of allocating the time to develop, test, and refine informative messages such as the explanatory essays to their final simple and concrete form. Involving experts in the initial stages improved the accuracy of the science and practical usability of the explanations, while interviewing non-experts allowed for an investigator-directed pre-message testing evaluation. In particular the non-expert interviews allowed for an empirical exploration of the metaphorical devices in terms of their helpfulness in organizing complex information, filling in of misunderstandings, and how receptive people are with such presentation of conceptual information. Additionally, the process allowed for "weeding out" problematic or insufficiently effective metaphors. For example, the original baseball metaphor, which was used to explain the difference between weather, climate and climate change, was replaced before the third study based both on recommendations of experts and the unhelpfulness exhibited during the non-expert interviews. Finally this demonstrated that the research methodology is a replicable model for future research, which can further improve explanatory metaphors for climate change communication, as well as other communication techniques for climate change discourse and other complex concepts.

How metaphors theoretically work and how message recipients process metaphors were strongly considered when developing the essays in order to achieve positive outcomes or intended goals. Four different climate change concepts were paired with metaphorical explanations as climate change is a broad and complex issue, and there is not just a single climate change concept that climate scientists, the media, and others involved in climate change discourse communicate about. The importance of choosing familiar base concepts was demonstrated in the results of the message testing experiment, inline with the literature which has examined the effectiveness of metaphors. Similarly it was also emphasized that the selection of familiarity of a target concept also plays a role in a metaphorical explanation having a desired effect.

A final theoretical implication, and perhaps an area of future study, is to understand how the written explanatory passages are likely different than hearing the same message. The mixed results of the effectiveness of metaphors as well as the mostly non-significant results calls into question whether the modality of presentation has an additional effect on changing individuals understanding and belief certainty of climate change. While reading, in the case of all the studies presented here, allows for more time to process the information and even revisit the information presented, listening to a speaker may have an alternative influence (Sopory & Dillard, 2002; van Dijk, 1987). Sopory and Dillard in conducting a meta-analysis regarding the persuasive power of metaphor actually found that the persuasiveness of audio is more persuasive than in writing. This is perhaps due to the fact that written information provides the time and thus opportunity for irrelevant connections to be made between base and target concepts. This is unlike in an auditory exposure to a metaphor in which processing is more immediate thus there is less time to over-think and come to inaccurate conclusions. Participants in the message testing experiment did take several minutes (on average, 5 minutes) to read the essay before continuing on to the post-test questionnaire and this perhaps negatively influenced post-test responses. However in the interviews, non-experts reading the essays had a face-to-face opportunity to discuss what they read thus any misperceptions, inaccuracies, or confusion could be talked through, avoiding negative outcomes with regards to understanding and perception of climate change.

6.4 Practical Implications

In terms of practical implications of the research conducted, some recommendations can be made for scientists and communication practitioners interested in using metaphors when performing any type of climate change outreach with lay audiences. The three sequential studies certainly highlight the importance of developing, testing, and refining the structure of climate change information and messages. Applying such a methodology, even on a smaller scale would be beneficial to the communicator to ensure successful translation of science. Such possibilities of smaller scale of 'pre-testing' a metaphor would be sharing explanations of climate science metaphors with other colleagues to determine if the metaphor is truly appropriate, check for holes in the metaphor that can cause greater confusion as opposed to clarity, and of course confirm the accuracy of the comparison and the science explained. Testing the metaphorical explanation, for example with students, before presenting it at a public outreach event is another opportunity to gauge whether the explanation will resonate with others. As noted by nearly all experts interviewed in the first study, it is well recognized that knowing who your audience is (e.g. adults, children, gardeners, an insurance company, etc.) can also serve as a guide in choosing not only an appropriate climate concept to talk about but also an appropriate base concept to use to compare the target climate concept. Knowing one's audience is important in choosing base concepts for comparison to the target concept that others are familiar with, not just what an expert believes or assumes other people are familiar with.

Metaphors can be an important framing tool that play a role in reasoning and decision making (Thibodeau & Boroditsky, 2013; Thibodeau & Durgin, 2008), but it is important to understand the limitations and virtues of metaphors. Additionally it is important to have a clear set of goals or desired outcomes so that the metaphor created and used is done so purposefully. As addressed in earlier chapters, metaphors are valuable in that they help conceptualize problems, situations, and complexities but if metaphors are inappropriately used or constructed an audience can be misled. The results of the message testing experiment demonstrated that providing an explanation of the frequency of extreme weather events and the increasing rate carbon dioxide significantly increased individual's understanding when the explanation involved science and metaphor together as opposed to science only. These two concepts are complex and involve statistics (frequency, rates). However, there were no significant differences between explanation types for the enhanced greenhouse effect and weather, climate and climate change topics. For practitioners, this provides some evidence that not every metaphor necessarily improves understanding as theorized. These results also demonstrate that some concepts may not need the additional metaphorical comparison to clearly explain the concept assuming the science itself is made simple and clear. In the case of the enhanced greenhouse effect, an easy to follow mechanistic explanation was leveraged, while the topic of weather, climate and climate change employed concise and jargon-less definitions. In the case of strengthening attitudes about climate change, the results show that clear explanations involving a metaphor or not positively influences the belief certainty of the reality of climate change. There is however a persistent, though non-significant, trend that the combination of science and metaphor changes belief certainty more than science or metaphor alone.

6.5 Limitations

In general qualitative and quantitative research each have their drawbacks. Regarding the exploratory nature of the qualitative research that was conducted as part of this study, finding a clear end point was challenging as multiple combinations and permutations can be explored even further than they were. To overcome this, specific research goals were put into place to maintain focus on the research questions and purpose of the qualitative studies. This may also have inadvertently placed some bias, personal subjectivity, or restrictions on the outcome of the studies. Regarding quantitative survey-based research, one disadvantage is that participants cannot be asked for more information or to explain their responses to the forced response items, or the open-ended questions unlike in the face-to-face interviews that were conducted. Some open-ended responses written by participants were difficult to score in cases where a participant responded with incomplete thoughts, or in instances of not answering the question directly leaving the response that was articulated rather vaguely. However, these general limitations mentioned here were some factors, which determined why this dissertation followed a multiphase-mixed methods research design with two qualitative studies followed by a quantitative study. Following a multiphase mixed method research design allowed for a series of connected research questions, provide a bigger and more detailed picture, and allow for comparisons and connections between the results to be made. However, some other limitations were still encountered.

One limitation of this dissertation is the fact that four different climate change concepts were discussed in the interviews and subsequently examined in the survey as opposed to focusing on one concept. Incorporating this many concepts into a single interview session limited the depth of each topic discussion mostly due to practical time constraints. An additional tradeoff of this approach resulted in a reduced sample size per topic and explanation combination for the message testing survey. An alternative approach, which focused on one concept across all three studies, would have perhaps enabled a more in-depth analysis and greater insight into the mechanism by which metaphors affect the understanding and perception of a single climate change topic. This alternative approach also carries its own limitations depending on the single concept chosen. It certainly would add additional insight to conduct multiple, larger-scale single concept investigations.

Unequal variances in the dependent variables examined across all thirteen explanatory essays were a clear limitation that was revealed and specific to the message testing survey. Unequal variances violated the assumption of homogeneity of variance and resulted in biasing the results of both the ANOVA and ANCOVA analyses involving all thirteen treatment groups. In attempt to overcome this limitation and obtain equal variances, all variables involved in the analyses were log transformed. However, variances calculated from the log transformed values were still unequal, hence a subsequent decision was made to perform the analyses per topic where variances were determined to be equal and the homogeneity of variances was assumed. Examining each topic separately in this manner reduced the generalizability of the experimental results and thus, direct comparisons of statistical significance could not be made. Any significant difference between groups for one topic therefore does not necessarily apply to another climate change concept. However, it should be pointed out that the within topic analyses offered insight into the effectiveness of metaphors explaining particular climate change concepts. Conducting multiple ANOVAs instead of a single MANOVA also did not allow for any relationship between the dependent variables – change in understanding and change in belief certainty – to be examined. Additional important limitations as a result of conducting the analyses on a per topic basis were a reduction in both the sample size and power of the results.

A few additional limitations specifically involved the dependent variable, the change in understanding. Open-ended questions asked participants before and after reading an explanatory essay to explain a climate change concept that they were randomly assigned. While changes in understanding could be compared between explanation types per topic, change in understanding scores could not be compared to the comparison group on a within subjects basis. Participants assigned to the comparison group essay were not asked the open-ended question after reading the essay because it was assumed their response would not change from the pre- to post-test. Also, some changes observed in understanding may have been due to the decision to remove the statement: 'If you do not know, it's okay to say, "I don't know."' This decision was made to encourage participants to reflect on what they had read. While this decision may have had such an effect, it is important to note some participants still responded to the question with "I don't know." Furthermore, the message testing experiment only measured understanding, as well as belief certainty, before reading an explanatory essay and shortly after. Therefore there is no conclusion that can be made whether such changes, either significant or not, would persist later (weeks, months).

Given the high levels of belief certainty among the participants (Qualtrics panelists) in study 3 at baseline, there was little room for belief certainty to increase after reading one of the randomly assigned essays. This is a potential concern for using online panels for message testing research. Furthermore, the high levels of belief certainty were also observed in the pre-test scores of MTurk worker participants in the pilot study. About two-thirds of the MTurk workers were either very or extremely sure that global warming is happening, which was similar to that observed for the Qualtrics panelists. MTurk specifically has received mixed reviews from researchers with some concluding, and warning, that surveys fielded via this platform include samples that are more politically liberal than a representative sample of the U.S. population (Berinsky, Huber, & Lenz, 2012), and have reduced validity and generalizability (Kahan, 2013). Others support its usage, though it is noted that researchers should proceed with caution and take into account specific flaws that may influence results (Leeper & Mullinix, 2014; Searles & Ryan, May 4, 2015). Other studies should be examined that have used these and other similar online platforms to see if others have found high belief certainty prior to participants receiving any information about climate change. If that is the case, researchers may want to consider other platforms for climate communication research because it may not truly represent the US level of belief certainty that global warming is happening.

6.6 Future Research

Perhaps one of the more obvious directions future research can go in is towards how long people remember what they read and learned about, and if there are long-term differences between what individuals understand based on how the climate change concept was explained to them. One way to examine if there are long-term effects would be to conduct a follow-up survey with the same individuals. A qualitative approach to examining mechanisms by which people remember and share information with others is through persistence trials. Persistence trials also allow for researchers to observe how and what participants understand, remember, and apply explanations and metaphors. In the case of the interviews conducted in study 2, it is possible the metaphors were not re-articulated because the hypothetical question (how would explain [concept] to someone else?) was not enough to simulate how the participants would explain to someone else. In a persistence trial, participants do not explain what they learned to a researcher; rather they explain to another participant. Kendall-Taylor et al. (2013) used persistence trials to examine how well an explanatory metaphor held up when being passed from one individual to another, and how participants use the metaphor to explain a concept to others. Volmert (2014) conducted persistence trials with two metaphors: climate's heart, and climate's spine. Analysis of the persistence trials demonstrated that the climate's heart metaphor, which explains the climate system, was highly effective. Since participants used the metaphor to explain the climate system to others, it was clear that the metaphor was memorable; and the fact that while participants made correct and appropriate associations between concepts, it had also improved their understanding of the climate system.

There are also several other research opportunities in assessing the effectiveness of metaphors for climate change communication. As mentioned in the limitations, another opportunity includes having one climate change concept as the focal concept. This would allow for interviews to go further in-depth into how non-experts understand the concept before as well as after reading an explanatory essay using a metaphor. Having one focal concept could also allow for interviews to involve reading two essays, one without an explanatory metaphor (science only) and a second with an explanatory metaphor (science + metaphor). This would allow participants to discuss, from their perspectives which explanation helped them understand the concept better. Other attitudes in addition to belief certainty could also be examined such as belief that climate change is human caused, trust in scientists, perception of scientific consensus, and communicator credibility. Another opportunity for future research on the effectiveness of metaphors for communicating climate change might include surveying attendees before and after a climate scientist's presentation in which a metaphor(s) were used to explain what is happening with Earth's climate.

6.7 Conclusion

This dissertation set out to examine to what extent, and if, metaphors are beneficial in transforming useful and fundamental climate change information into usable, understandable, and relatable information. In the first study, twelve expert interviews led to improved stimulus materials, in terms of validity, accuracy and usability for climate science outreach. Furthermore, Study 1 demonstrated that experts are either already using metaphors when talking to non-experts, or are interested in finding more ways to explain climate change concepts, including metaphors, that they can feel confident in using and connecting to their audiences. The non-expert interviews in Study 2 found that the participants in general are uncertain as to how to explain climate change and climate change related topics. After reading the essays however, they could add details that they had previously not known. While the non-experts gained clarity and understanding of the climate change topics and frequently stated the metaphors were helpful when reading the explanatory essays, very few re-articulated the metaphor in their explanations later. The two qualitative studies in effect allowed for both experts and non-experts to be engaged in the stimulus material development and enhance the meaning of the essays. The results of the message testing survey, Study 3, surfaced several non-significant trends in the change in understanding and change in belief certainty for the four climate change concepts. Overall, the outcomes emphasized that the usage of metaphors produce mixed results and for some topics metaphors tend to enhance the scientific explanation, while in other cases metaphors do not serve as an aid in explaining climate change concepts.

The three sequential studies highlight that metaphors are useful communication tools for experts; lay audiences find metaphors helpful, interesting, and assist in making the scientific information more memorable based on observations made during the lay interviews; and for some climate change topics, trends indicate explanations with metaphors benefit to some degree that both understanding and belief certainty that climate change is happening are positively influenced. While the results were not statistically significant, the trends nevertheless express that metaphors are not merely illustrative figures of speech that make language more elegant, but provide important context, structure and guidance for how people think, act, and comprehend. Lakoff and Johnson (1980, p. 146) further argue that, "It is reasonable enough to assume that words alone do not change reality. But changes in our conceptual system do change what is real for us and affect how we perceive the world and act upon those perceptions." In the case of the metaphors in the present studies, they ground the climate change concepts with relatable and tangible concepts with the purpose of improving awareness, understanding and belief in the reality of climate change. Through the structure the metaphors provide, they transform the complex scientific ambiguities into clear and simpler forms that vividly connect the issue to people's values, knowledge, emotions, and experiences. Considering the urgency of addressing climate change, it is important for climate scientists and other science communicators to use well-tested communication strategies with lay audiences. This research highlights the need for and importance of more deeply evaluating the effectiveness of a specific communication strategy for science communicators – metaphors – in the context of climate change as well as the significance of explaining the reality and importance of the issue clearly and concisely.

APPENDIX A – STUDY 1 MATERIALS

A.1 – Study 1 Interview Guide

***Prior to the interview*: Interviewees will be informed in the initial contact (email) that the topic of the interview will be the use of metaphors in climate science communication. They will be asked to come prepared to discuss some metaphors that they themselves use in explaining climate science concepts to the public.

At the beginning of the interview, participants will be presented with a consent form, reminded that the interview will be recorded, and take approximately 60 minutes. The interview will be semi-structured with some introductory questions, and the main portion of the interview will primarily be about the evaluation and validation of the pilot study stimulus materials.

Background information:

- Educational background, current job title/profession
- Experience with non-expert audiences?

To start, what climate science concepts do you sometimes attempt to clarify with the use of a metaphor (if any)? Any others?

For each topic listed, respondents will be asked to explain the climate concept to me, using their metaphor, as they normally would explain to a lay audience. When they are done with the explanation: *What is it about that metaphor that you find to be particularly helpful?* (*Anything else?*)

For each topic (weather & climate; greenhouse effect; increasing CO_2 in the atmosphere; & frequency of extreme weather events):

1. Please read the following short essay [science + metaphor], and highlight what you like (in green) and underline what you do not like, or don't find clear (in red). We will discuss once you have completed reading.
    a. Discuss and when needed follow-up with prompts.
        i. Overall, what are your thoughts about this explanation?
        ii. Walk through highlights/underlines: likes/dislikes, clarity, etc.
        iii. *If not addressed:* Is this something that you would find useful? Why or why not? Is the content of the passage accurate? Do you feel (or do you think others feel) confident and comfortable using these (and/or other) metaphors? Are there alternative explanations? Other techniques?

In closing, is there any other advice you can offer on how to effectively use metaphor in explaining climate science concepts to the public?

Anything else?

Neutral prompts:

- Can you tell me more about ___ ?
- Can you explain how ___ ?

A.2 – Study 1 Stimulus Materials for Expert Review

1) Why is the weather becoming more extreme?

A recent report written by over 300 leading American climate scientists reached the following conclusion: *Some types of extreme weather and climate events have increased in the United States, and worldwide, over the past 50 years, and these increases are related to human-caused global warming.*

For the past 100 years or so, people have been burning large amounts of fossil fuels to generate electricity and to operate cars, trucks, trains, airplanes, and ships. The burning of fossil fuels has released large amounts of carbon dioxide and other "greenhouse gases" into the atmosphere. These gases accumulate and trap infrared light and heat that otherwise would radiate back out into space. The consequence is that Earth has gotten warmer.

As a result, the world has warmed rapidly over the past 50 years, and the warming has triggered many other changes to the Earth's climate. During this time, there have been increases in heat waves and heavy downpours across the United States. Many regions of the country have also had increases in severe floods, droughts and severe winter storms.

When an extreme weather event occurs, people often want to know if it was caused by climate change. Take for example the severe drought currently in California. There is no way for scientists to directly answer that question because many factors contribute to every weather and climate event. However, scientists have developed methods to estimate how much climate change contributed to a specific extreme event.

To understand how scientists do this, it helps to think about a similar question: How can we know if a homerun hit by a baseball player who takes steroids was caused by the steroids, or not? We can do this by looking at the player's batting statistics both before and after he started taking steroids. For example, if the player hit 20% more homeruns after taking steroids than before, we can conclude that any given homerun the player hit after taking steroids was caused partially (about 20%) by the steroids. This method is similar to how climate scientists can determine how much climate change and heat-trapping gases have contributed to a specific extreme weather event.

Scientists first look at historical records to determine how often a specific kind of event happened in the past. These events happened before carbon dioxide and other heat-trapping gases began to accumulate in the atmosphere. Such records include direct and indirect observations of temperature and precipitation. For example, the size of tree rings and air bubbles in ice cores are historical measures for temperature, precipitation and greenhouse gas levels. Scientists then compare historical frequencies based on these measures with how often types of events are happening now, after heat-trapping gases began to accumulate in the atmosphere. Finally, they compare the two sets of numbers. For example, if an extreme event is happening 20% more frequently now than in the past, we can conclude that that the event was caused partially (about 20%) by the accumulation of heat-trapping gases in the atmosphere.

The important point to remember is that the accumulation of heat-trapping gases from human activities in the Earth's atmosphere is increasing the frequency and severity of some categories extreme weather and climate events in the United States.

2) Why is the level of carbon dioxide in the atmosphere increasing temperatures?

The level of carbon dioxide (CO_2), a heat-trapping gas, reached a milestone in 2013 of 400 parts per million (ppm). Scientists have been measuring and tracking CO_2 at the Mauna Loa Observatory in Hawaii since 1958. At the time, CO_2 levels were at 315 ppm. The rate of increase we are observing now is approximately 100 times faster than at the end of the last Ice Age, when CO_2 levels were much lower than today.

All of the Earth's carbon is stored in one of four places: the atmosphere, the oceans, the land surface, and deep below the surface. Carbon fluctuates among these places. When Earth's climate is stable, carbon is pretty evenly distributed among them. Carbon that is emitted into the atmosphere as CO_2 helps to keep our Earth warm. When carbon dioxide levels in the atmosphere are low, about 200 ppm, glaciers grow in size and cover large portions of the planet and the Earth enters an ice age. When carbon dioxide levels are high, about 300 ppm or higher, the planet warms, and the ice recedes.

Over the past several million years, natural variations in the balance between carbon on land, in the oceans, and in the atmosphere, led to the cycle of ice ages. Over the past 100 years or so, the burning of fossil fuels and large-scale deforestation has significantly changed the balance such that much more carbon is accumulating in the atmosphere.

The bathtub is a helpful way to think about this situation. The amount of water in the tub represents the amount of CO_2 in the atmosphere. The amount of water flowing into the tub through the faucet represents CO_2 being released in the atmosphere. The amount of water leaving the tub through the drain represents CO_2 being captured by plants and deposited in the soil. Historically, the amount of CO_2 flowing in, and the amount draining out, have waxed and waned a bit. However, the tub never over-flowed. Over the past 100 years, the burning of fossil fuels has dramatically increased the rate of flow into the tub. Deforestation has also dramatically decreased the rate of flow out. Therefore, the level of water (that is, CO_2) in the tub is now rapidly rising.

Plants use CO_2 during photosynthesis and store the carbon in wood, leaves, and roots. Animals consume the plants, and microorganisms decompose them. Both processes result in the breakdown of plant tissues. Much of the organic carbon released by these processes is stored in soils. A significant portion of plant and soil carbon reenters the atmosphere during forest fires. Cutting down and burning trees to convert forested land for other uses releases carbon too. A reduction in the amount of forest lessens its ability to remove CO_2 from the atmosphere via photosynthesis. The balance between the Earth's carbon storage areas is out of balance, and too much CO_2 is in the atmosphere.

The combination of burning fossil fuels and deforestation has resulted in an increase in the concentration of CO_2 in the atmosphere. Scientists' observations of records from the past and present, as well as projections show a strong relationship between temperature and the concentration of CO_2. Observing the continuation of this trend confirms that when CO_2 concentration goes up, temperature goes up.

3) What is the "Greenhouse Effect" and how is it related to global climate change?

The Earth's atmosphere plays a large role in shaping our climate. If it were not for the "greenhouse gases" that trap heat in the atmosphere, the Earth would be a very cold place. These heat-trapping gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and chlorofluorocarbons (CFCs).

For the past 100 years or so, people have been burning large amounts of fossil fuels to generate electricity and to operate cars, trucks, trains, airplanes, and ships. The burning of fossil fuels has released large amounts of carbon dioxide and other greenhouse gases into the atmosphere. These gases accumulate and trap infrared light and heat that otherwise would radiate back out into space; this is called the "greenhouse effect." The consequence is that Earth has gotten warmer.

Some people say that the "greenhouse effect" should be named the "parked car effect." This is because the greenhouse effect is similar to what happens when a car is parked outside in the summer sun. With the greenhouse effect, carbon dioxide and other greenhouse gases let sunlight in, but then trap heat in the atmosphere near Earth's surface. With the parked car effect, the glass windows let sunlight in, but then trap the heat that is created inside the car.

The actual mechanism of overheating in cars is a lack of convection, or the lack of air movement. Sunlight enters and hits the dashboard and upholstery, which heats up and warms the interior air. But the heat cannot escape, so the inside of the car gets hotter and hotter. Although this is different from how greenhouse gases trap heat in the atmosphere, the result is the same. In both processes, sunlight "checks in" but heat cannot "check out."

The greenhouse effect is Earths' natural heating process. Specific gases in the atmosphere, called greenhouse gases, absorb and hold the sun's infrared radiation, causing the lower atmosphere and the Earth's surface to warm.

In the mid-1950s, scientists began to study the accumulation of carbon dioxide and other greenhouse gases in the atmosphere produced by the burning of large amounts of fossil fuels. Further studies indicated that there might be an *enhanced* greenhouse effect. Their concern was, that by enhancing the greenhouse effect, as a result of the additional greenhouse gases in the atmosphere, the Earth would get warmer.

The Earth absorbs light from the sun, which is mostly visible light. Some of this light, infrared light, gets reflected off the surface of the Earth back toward space. Greenhouse gases in the atmosphere, such as carbon dioxide and methane, let visible light pass through but absorb infrared light. This causes the atmosphere to retain heat. This energy can be absorbed and emitted by the atmosphere many times before it eventually returns to outer space. This trapping of heat by greenhouse gases in the atmosphere is called the "greenhouse effect." Without it, the Earth's average surface temperature would be about 50 degrees Fahrenheit cooler, which is well below the freezing point for ice.

Since 1900, the amount of carbon dioxide in the atmosphere has increased by almost 40%, and methane has almost tripled. These increases cause extra infrared light absorption, meaning an enhanced greenhouse effect, which has caused Earth to heat up above its typical temperature range.

In summary, the Earth's greenhouse effect is what makes this planet suitable for life as we know it. While the greenhouse effect helps regulate Earth's temperature, an increase in the amount of carbon dioxide and other greenhouse gases in the atmosphere has warmed the Earth over the past 100 years.

4) What is the difference between weather and climate?

To understand climate change, it helps to understand the difference between weather and climate. Weather and climate are related to each other, but they are distinct in important ways.

Weather is the condition of the atmosphere at a particular time and place. Weather changes frequently from day to day, and sometimes even in the span of a few minutes. To understand and predict the weather, meteorologists use computerized weather models. With this data, meteorologists are able to make fairly accurate predictions about the weather, called forecasts, for up to five days.

Climate is the average of weather conditions in a particular place over a long period of time, typically 30 years. The climate in a particular place, and especially the climate of the Earth overall is usually very stable. If the climate changes at all, it usually changes slowly. To understand and predict the climate, climatologists use computerized climate models. With this data, climatologists are able to make fairly accurate predictions about the climate, called projections, for five decades or more.

One way to understand the difference between weather and climate is to compare them to Major League Baseball (MLB). Weather is like one player at bat, swinging one time. His swing may result in a strike, a foul, a single, a double, a triple, or a homerun.

The climate of a given region, however, is like the entire team's batting average over the past 30-years. And the climate of the Earth overall is like the batting average of all MLB teams over the past 30 years. We wouldn't be surprised to see a given player's batting average rise and fall over the span of a few games, but we would be surprised if the batting average of the entire MLB began to rise, or fall, rapidly.

Weather is dependent on many factors that can change quite quickly. These include the movements of storm systems, warm and cold fronts, and other atmospheric disturbances. It is also driven by the rapid daily cycle of day and night, and the somewhat slower cycle of the seasons. For example, days are warmer than nights, and summers are warmer than winters.

Climate is determined primarily by factors that change only slowly, and by other factors that don't change at all. These include the average temperature and precipitation in a region. Other factors that influence the climate of a region are its latitude and elevation, bodies of water in or near the region, ocean currents, and vegetation.

Compared to weather, the climate is normally very stable. Over the past 50 years, however, the Earth's average temperature has been increasing rapidly, and the climate is changing as a result. Research by climatologists has proven that increasing levels of heat-trapping gases in our atmosphere, including carbon dioxide and other "greenhouse gases" are causing the warming. These heat-trapping gases are being produced and warming is occurring at a much faster rate than at anytime in the past 65 million years. Will we continue to occasionally have unusually cold winters, and mild summers? We will. On average, our winters and summers are projected to continue getting warmer, as they have been for the past 50 years.

A.3 – List of expert-generated metaphors from interviews by topic

Frequency of Extreme Weather	Increasing Rate of Carbon Dioxide	Enhanced Greenhouse Effect	Difference between Weather and Climate
• Loaded dice • Recipe • Ocean tides on the beach	• Checkbook balance • Balancing a budget or bank account	• Adding blankets • Earth as a jar (container) with a lid	• Mood & personality • Athlete & coach • Child & parent • Stock market • Dog walking vs. human walking • Seasonal clothing & entire wardrobe

A.4 – Wilcoxon Signed Rank Test Result Tables

Table A.4.1. Overall Essay

Essay	Mean	Median	Test statistic (*T*)	z-score (*z*)	*p*	Effect size (*r*)
Extreme Weather	0.03	-0.02	34.5	0.13	0.894	0.01
Increasing CO_2	0.1	0.05	54.5	1.22	0.223	0.06
Enhanced Greenhouse Effect	-0.05	-0.06	14	-1.38	0.168	-0.07
Weather and Climate	0.03	0.06	42.5	0.85	0.395	0.04

Table A.4.2. Science Paragraphs

Essay	Mean	Median	Test statistic (*T*)	z-score (*z*)	*p*	Effect size (*r*)
Extreme Weather	0.03	-0.01	30.5	0.307	0.759	0.02
Increasing CO_2	0.01	-0.03	36.5	-0.2	0.844	-0.01
Enhanced Greenhouse Effect	-0.13	-0.17	13.5	-1.75	0.08	-0.12
Weather and Climate	-0.01	-0.06	30.5	-0.23	0.821	-0.02

Table A.4.3. Metaphor Paragraphs

Essay	Mean	Median	Test statistic (*T*)	z-score (*z*)	*p*	Effect size (*r*)
Extreme Weather	0.19	0	15.5	1.078	0.281	0.16
Increasing CO_2	0.23	0.06	35.5	1.55	0.122	0.15
Enhanced Greenhouse Effect	0	0.056	27	-0.05	0.959	0.00
Weather and Climate	0.35	0.5	44	1.71	0.087	0.20

Table A.4.4. Comparing Science and Metaphor Sections

Essay	Test statistic (*T*)	z-score (*z*)	*p*	Effect size (*r*)
Extreme Weather	22.5	-0.94	0.35	-0.06
Increasing CO_2	16.5	-1.77	0.077	-0.10
Enhanced Greenhouse Effect	15	-1.6	0.109	-0.09
Weather and Climate	16.5	-1.77	0.077	-0.11

APPENDIX B. STUDY 2 MATERIALS

B.1 – Study 2 Screening Questionnaire for Non-Expert Interviews

1) What do you think? Is climate change is happening?
- Yes
- No
- Don't know

    2A) ***IF YES* to 1:** How sure are you that climate change is happening?
    - Extremely sure
    - Very sure
    - Somewhat sure
    - Not at all sure

    2B) ***IF NO* to 1:** How sure are you that climate change is not happening?
    - Extremely sure
    - Very sure
    - Somewhat sure
    - Not at all sure

3) Which one of the following statements describes you best?
- I'm very certain that human-caused global warming is happening, and I'm very worried about it.
- I'm moderately certain that human-caused global warming is happening, and I'm somewhat worried about it.
- I suspect that global warming is happening and although I'm not certain if it is human-caused or not, I am just a little worried about it.
- I really haven't thought much about global warming, so I'm not sure what to think about it.
- I suspect that global warming is not happening, or isn't human-caused, but if it is I am fairly sure that it won't be a problem during the next several decades.

I'm moderately or very certain that global warming is not happening, or if it is, that it isn't human caused, and that it isn't a problem.

B.2 – Study 2 Interview Guide

Neutral prompts:

- Can you tell me more about ___ ?
- Can you explain how ___ ?
- Does __ bring anything else to mind?
- If you were going to explain [concept] to someone else, is there anything you would say differently or add to what you have said?

Prior to interview with introduction & recruitment: Have they heard of global warming, which is also sometimes called climate change?

Opening: At the beginning of the interview, participants will be presented with a consent form, reminded that the interview will be recorded and take approximately 30 to 60 minutes, and if at any time they have questions or comments they may feel free to interject.

Opening questions:

1. What's the first thing that comes to mind when you think of climate change? What are the most important things that you feel people should know about climate change?
2. What can you tell me about the causes of climate change?
    a. *Probe, if needed:* How would you explain climate change to a family member or friend?
3. What can you tell me about the greenhouse effect that scientists say is the reason why global warming is happening? *What do you know about CO_2 and the atmosphere?*
4. What can you tell me about the relationship between weather and climate?
    a. *Follow-up, if necessary:* Relationship between extreme weather and climate change?
5. And last, what can you tell me about how climate change is influencing the weather?

Next we will go through a few short essays, discuss them, and talk about your current understandings of climate change. Use the green and red pens to highlight what you find clear or like (green), and underline what you don't like or do not understand clearly (red). The science and issue of climate change is highly complex and I am interested in what you think about the passages and what you understand about climate change. This is not a test of your knowledge, but rather has the purpose to understand ways of understanding of complex scientific topics.

Weather & Climate

1. Please read the following short essay [science + metaphor], and highlight – the sentences or words – in green that are helpful to you to better understanding what is being discussed, and highlight in red the sentences and words that you feel are unhelpful or unclear. [When completed, ask the following questions.]
    a. What is your overall reaction to this essay? Do you have any other big picture reactions to this essay?
    b. Please tell me about each of the passages you marked in green or red. What did you like, or dislike, about each?
    c. Is there anything else I should know about your reaction to this essay?
    d. Now please turn the essay over and tell me how you would explain the relationship between ***climate and weather*** to an intelligent 8th grader.

[Enhanced] Greenhouse Effect

1. Please read the following short essay (science + metaphor), and highlight – the sentences or words – in green that are helpful to you to better understanding what is being discussed, and highlight in red the sentences and words that you feel are unhelpful or unclear. [When completed, ask the following questions.]
    a. What is your overall reaction to this essay? Do you have any other big picture reactions to this essay?
    b. Please tell me about each of the passages you marked in green or red. What did you like, or dislike, about each?
    c. Is there anything else I should know about your reaction to this essay?
    d. Now please turn the essay over and tell me how you would explain the relationship between ***the greenhouse effect and climate change*** to an intelligent 8th grader.

CO_2 & the atmosphere

1. Please read the following short essay (science + metaphor), and highlight – the sentences or words – in green that are helpful to you to better understanding what is being discussed, and highlight in red the sentences and words that you feel are unhelpful or unclear. [When completed, ask the following questions.]
    a. What is your overall reaction to this essay? Do you have any other big picture reactions to this essay?
    b. Please tell me about each of the passages you marked in green or red. What did you like, or dislike, about each?
    c. Is there anything else I should know about your reaction to this essay?
    d. Now please turn the essay over and tell me how you would explain the relationship between ***carbon dioxide*** (other greenhouse gases?) ***and climate change*** to an intelligent 8th grader.

Frequency of extreme weather events

1. Please read the following short essay (science + metaphor), and highlight – the sentences or words – in green that are helpful to you to better understanding what is being discussed, and highlight in red the sentences and words that you feel are unhelpful or unclear. [When completed, ask the following questions.]
    a. What is your overall reaction to this essay? Do you have any other big picture reactions to this essay?
    b. Please tell me about each of the passages you marked in green or red. What did you like, or dislike, about each?
    c. Is there anything else I should know about your reaction to this essay?
    d. Now please turn the essay over and tell me how you would explain the relationship between ***extreme weather events and climate change*** to an intelligent 8th grader.

Closing question:

If you were to now explain climate change to a family member or friend, how might you explain it to them?

In closing:

[Thank participant]

- How was it to participate in this interview?
- Were any questions too hard, unclear, or unpleasant to answer?
- Were there any issues related to climate, weather, carbon dioxide and the atmosphere, extreme weather, or the greenhouse effect that we did not get to discuss? What are those issues?

B.3 – Study 2 Stimulus Materials for Non-Expert Review

1) Why are extreme weather events becoming more frequent?

When an extreme weather event occurs, people often want to know why they are happening more frequently. A recent report by over 300 leading American climate scientists reached the following conclusion: *Some types of extreme weather and climate events have increased in the United States, and worldwide, over the past 50 years, and these increases are related to human caused global warming.*

To understand how scientists study this, it helps to think about a similar question: How do we know if a homerun hit by a baseball player who takes steroids was caused by the steroids, or not? We can look at the player's batting statistics both before and after he started taking steroids. For example, a player hit more homeruns after taking steroids than before. We can conclude that the steroids likely caused any given homerun the player hit after taking steroids. This method is similar to how climate scientists look at the frequency of extreme weather events. Greenhouse gases, the steroids of the climate system, have been measured before and after human activities added to their abundance in the atmosphere. These measurements allow scientists to observe how much the gases have contributed to climate change and extreme weather events.

For the past 100 years or so, people have been burning large amounts of fossil fuels – coal, oil, and gas – for electricity, and transportation. The burning of fossil fuels has released large amounts of carbon dioxide and other greenhouse gases, which trap heat in the atmosphere. The consequence is that Earth has gotten warmer, and has rapidly warmed over the past 50 years. During this time, there have been increases in heat waves and heavy downpours across the United States. Many regions of the country have also seen increases in severe floods, droughts, and extreme winter storms. One recent example of such an event is the severe drought in California.

Since there are many factors that contribute to every weather and climate event, it is difficult for scientists to directly answer the title question. However, scientists have developed methods to estimate how much climate change and greenhouse gases have contributed to a specific extreme event. For example, observations of temperature, precipitation, and greenhouse gases can be compared to historical records and proxy data collected over the last 50 to 100 years. Through these comparisons, scientists estimate how the frequencies of certain weather and climate events have changed with the increase of greenhouse gases. If an extreme event is observed more frequently now than in the past, this provides evidence that it is likely the frequency of that type of event was influenced by the accumulation of heat-trapping gases in the atmosphere.

The important point to remember is that the accumulation of heat-trapping greenhouse gases from human activities in the Earth's atmosphere is increasing the frequency and severity of some categories of extreme weather and climate events in the United States.

2) Why is the level of carbon dioxide in the atmosphere increasing temperatures?

The level of carbon dioxide (CO_2), a heat-trapping greenhouse gas, reached a milestone in 2013 of 400 parts per million (ppm). Scientists have been measuring and tracking CO_2 at the Mauna Loa Observatory in Hawaii since 1958. At the time, CO_2 levels were at 315 ppm. Over the past several million years, natural variations in the balance between carbon on Earth have played a role in warming and cooling periods. Over the past 100 years or so, the burning of fossil fuels – coal, oil, and gas – and deforestation has significantly changed the balance. The rate of increase we are observing now is approximately 100 times faster than at the end of the last Ice Age, when CO_2 levels were much lower than today.

An overflowing bathtub is a helpful way to think about this situation. The amount of water already in the tub represents the natural amount of CO_2 in the atmosphere. The amount of water flowing into the tub through the faucet represents human activity CO_2 being released in the atmosphere. The amount of water leaving the tub through the drain represents CO_2 being captured by plants and deposited in the soil. Historically, the amount of CO_2 flowing in, and the amount draining out, have been balanced. Over the past 100 years, the burning of fossil fuels has dramatically increased the rate of flow into the atmosphere. Deforestation has also dramatically decreased the rate of flow out. Therefore, the level of water (CO_2) in the tub is now rapidly rising and we are overflowing the tub (increasing global temperatures).

All of the Earth's carbon is stored in one of four places: the atmosphere, the oceans, the land surface, and deep below the surface. Carbon fluctuates among these places. When Earth's climate is stable, carbon is balanced among them. Carbon that is emitted into the atmosphere as CO_2 helps to keep our Earth warm. When carbon dioxide levels in the atmosphere are low, about 200 ppm, the Earth's average temperature cools and has been associated with past ice ages. When carbon dioxide levels are high, about 300 ppm or higher, the planet warms, altering weather patterns and melting sea and land surface ice. Scientists' observations of records from the past and present, as well as projections show a strong relationship between temperature and the concentration of CO_2.

Plants use CO_2 during photosynthesis and store the carbon in wood, leaves, and roots. A reduction in the amount of forested area reduces the removal of CO_2 from the atmosphere via photosynthesis. Carbon from under the Earth's surface that is burned, fossil fuels, add to the carbon in the atmosphere. With less forested land, it cannot return as quickly to the ground as it has in the past. The balance between the Earth's carbon storage areas is off kilter.

The important point to remember is that there is an increasing accumulation of heat-trapping greenhouse gases in the Earth's atmosphere from human activities. Observing the continuation of this trend confirms that when CO_2 concentration goes up, temperature goes up. This is resulting in climactic changes impacting our natural and social world.

3) What is the Greenhouse Effect and how is it related to global climate change?

The Earth's atmosphere plays a large role in shaping our weather and climate. The greenhouse effect is Earth's natural heating process. Specific gases in the atmosphere, called greenhouse gases, absorb and hold the sun's energy, causing the lower atmosphere and the Earth's surface to warm. If it were not for the greenhouse gases, the Earth would be cold and uninhabitable. These heat-trapping gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), ozone (O_3), and chlorofluorocarbons (CFCs).

Some people say that the greenhouse effect should be named the "parked car effect." This is because the greenhouse effect is similar to what happens when a car is parked outside in the summer sun with the windows closed. With the greenhouse effect, carbon dioxide and other greenhouse gases let sunlight in, but then trap heat in the atmosphere. With the parked car effect, the glass windows let sunlight in, but then trap the heat that is created inside the car. Sunlight enters and hits the dashboard and upholstery, which heats up and warms the interior air. But the heat cannot escape, so the inside of the car gets hotter and hotter; and this we know can be dangerous for children and pets if they are left inside. In both processes, sunlight "checks in" but heat cannot "check out." Although the actual mechanism in the atmosphere is different, the result is the same.

The greenhouse effect on Earth absorbs energy from the sun, and some of this energy is reflected off the Earth's surface and back into space. However, greenhouse gases prevent some of that energy from escaping, and instead absorb the energy. This causes the atmosphere to retain heat. This energy can be absorbed and emitted by the atmosphere many times before it eventually returns to outer space. Without this process, the Earth's average surface temperature would be about 50 degrees Fahrenheit cooler, which is well below the freezing point for water.

For the past 100 years or so, people have been burning large amounts of fossil fuels – coal, oil, and gas – for electricity, and transportation. The burning of fossil fuels has released large amounts of carbon dioxide and other greenhouse gases into the atmosphere. Scientists have studied the impacts of the accumulation of carbon dioxide and other greenhouse gases in the atmosphere means. Evidence from these studies suggests there is an *enhanced* greenhouse effect. By enhancing the greenhouse effect, as a result of the additional greenhouse gases in the atmosphere, the Earth is getting warmer. In fact, since 1900, the amount of carbon dioxide in the atmosphere has increased by almost 40%, and methane has almost tripled. These increases cause extra energy absorption, causing the Earth to heat up above its typical temperature range.

In summary, while the greenhouse effect plays a vital role in regulating Earth's temperature, over the past 100 years the process has been enhanced with the increasing amounts of greenhouse gases. In turn, global temperatures have rapidly increased and changes in climate have been accelerating.

4) What is the difference between weather and climate?

The saying goes: weather is what you get, and climate is what you expect. With climate change however, it is more complicated than that. Understanding the relationship between the weather and climate helps to understand climate change.

One way to understand the relationship between weather and climate is to compare them to baseball statistics. Weather is like one player at bat, swinging one time. His swing may result in a strike, a foul, a single, a double, a triple, or a homerun. You get what you get when a player is up at bat. The climate of a given region, however, is like a player's batting average over 30-years. And the climate of the Earth overall is like the batting average of all players in Major League Baseball over the past 30 years. Batting averages change, but any big change is due to an external factor like steroid usage, or pitcher mound height. If the outcomes up at bat were wildly inconsistent thus altering the batting averages, we would be suspicious that something out of the ordinary had changed.

Weather is the condition of the atmosphere at a particular time and place. Weather changes frequently from day to day, and sometimes even in the span of a few minutes. Climate is the average of weather conditions in a particular place over a long period of time, typically 30 years. The climate in a particular place, and especially the climate of the Earth overall is usually very stable in a human lifetime. If the climate changes at all, it usually changes slowly.

To understand and predict weather and climate, very similar models for each are used that incorporate the many different factors. These models though, differ in space and time. Weather forecast models, for example make accurate predictions for up to about seven days and for a specific place, or your local region. Climate models make projections for much larger regions, and on longer timescales, even up to 100 years into the future.

Weather is dependent on many factors that can change quite quickly. These include the movements of storm systems, as well as warm and cold fronts. It is also driven by the rapid daily cycle of day and night, and the seasons. For example, days are warmer than nights, and summers are warmer than winters. Climate is determined primarily by factors that change slowly, and by other factors that don't change. These include, respectively, the average temperature and precipitation in a region, and a region's latitude and elevation, bodies of water in or near the region, ocean currents, and vegetation.

Compared to weather, the climate changes much more slowly. Over the past 50 years, however, the Earth's average temperature has been occurring at a faster rate than in the last 65 million years, and the climate is changing as a result. Research by climatologists have provided evidence that increasing levels of heat-trapping gases in our atmosphere, including carbon dioxide and other greenhouse gases are major factors contributing to the warming. Will we continue to occasionally have unusually cold winters, and mild summers? We will, but on average our winters and summers are projected to continue getting warmer, as has been the pattern for the past 50 years.

B.4 – Wilcoxon Signed Rank Test Result Tables

Table A.4.1. Overall Essay

Essay	Mean	Median	Test statistic (T)	z-score (z)	*p*	Effect size (*r*)
Extreme Weather	0.14	0.12	312.5	2.50	0.012	0.10
Increasing CO_2	0.25	0.17	367.5	3.75	0.000	0.13
Enhanced Greenhouse Effect	0.27	0.23	339.0	3.61	0.000	0.13
Weather and Climate	0.09	0.16	341.5	3.67	0.000	0.12

Table A.4.2. Science Paragraphs

Essay	Mean	Median	Test statistic (T)	z-score (z)	*p*	Effect size (*r*)
Extreme Weather	0.17	0.09	261.0	2.67	0.008	0.14
Increasing CO_2	0.26	0.13	259.5	3.14	0.002	0.13
Enhanced Greenhouse Effect	0.12	0.08	226.5	1.73	0.084	0.09
Weather and Climate	0.28	0.23	297.5	4.22	0.000	0.20

Table A.4.3. Metaphor Paragraphs

Essay	Mean	Median	Test statistic (T)	z-score (z)	*p*	Effect size (*r*)
Extreme Weather	0.08	0.14	189.0	1.57	0.116	0.12
Increasing CO_2	0.24	0.13	270.0	3.47	0.001	0.22
Enhanced Greenhouse Effect	0.31	0.19	293.0	3.54	0.000	0.23
Weather and Climate	0.14	0.13	181.5	1.79	0.073	0.12

Table A.4.4. Comparing Science and Metaphor Sections

Essay	Test statistic (*T*)	z-score *(z)*	*p*	Effect size (*r*)
Extreme Weather	197.0	0.19	0.847	0.01
Increasing CO_2	223.5	0.83	0.406	0.03
Enhanced Greenhouse Effect	95.0	-2.05	0.041	-0.08
Weather and Climate	237.0	1.15	0.249	0.04

APPENDIX C. STUDY 3 MATERIALS

C.1 – Message Testing Survey Instrument

We first have a few questions about you.

1. What is your gender?
   - ❍ Male
   - ❍ Female
   - ❍ Other

2. What is your age?
   - ❍ 18-24
   - ❍ 25-34
   - ❍ 35-44
   - ❍ 45-54
   - ❍ 55-64
   - ❍ 65-74
   - ❍ 75+

****

3. Please indicate how familiar you feel you are with the following topics:
[*Statements will be in randomized order*]

	Not at all familiar	Slightly familiar	Somewhat familiar	Moderately familiar	Extremely familiar
[a] The increasing frequency of extreme weather events.	❍	❍	❍	❍	❍
[b] How steroid use effects baseball players	❍	❍	❍	❍	❍
[c] The rate at which carbon dioxide (CO_2) is increasing in the atmosphere [d] How water drains from a bathtub	❍	❍	❍	❍	❍
[e] The "greenhouse effect" (that is, how "greenhouse gases"	❍	❍	❍	❍	❍

keep the planet warm)					
[f] How sunlight causes cars to heat up	❍	❍	❍	❍	❍
[g] Climate change is leading to changes in our weather and climate over time.	❍	❍	❍	❍	❍
[h] The difference between a person's mood and their personality [i] Please select Moderately Familiar	❍	❍	❍	❍	❍

****

Climate change refers to the long-term change in Earth's climate, or in the climate of a region or a city. Scientific observations have been made that show the world's average temperature has been getting warmer over the past century, which is changing the weather and climate in most regions of the world.

4. What do you think: is climate change happening?
   - ❍ Yes
   - ❍ No
   - ❍ Don't know

5a. ***If 'yes' to 3:*** How sure are you that climate change is happening?
   - ❍ Extremely sure
   - ❍ Very sure
   - ❍ Somewhat sure
   - ❍ Not sure at all

5b. ***If 'no' to 3:*** How sure are you that climate change is not happening?
   - ❍ Extremely sure
   - ❍ Very sure
   - ❍ Somewhat sure
   - ❍ Not sure at all

****

6. To the best of your knowledge, what proportion of global warming over the past several hundred years has been caused by human activity (versus natural changes in the environment)? Select "Not Applicable" if you do not believe there has been global warming over the past several hundred years.

7. How much do you trust or distrust scientists as a source of information about climate change?

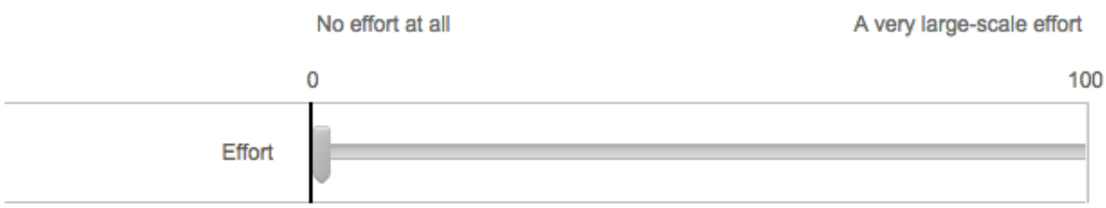
- ❍ Strongly distrust
- ❍ Somewhat distrust
- ❍ Undecided
- ❍ Somewhat trust
- ❍ Strongly trust

****

8. How important is the issue of climate change to you personally?

- ❍ Not at all important
- ❍ Not too important
- ❍ Somewhat important
- ❍ Very important
- ❍ Extremely important

9. How big of an effort should the United States make to address climate change?



10. How much of a priority do you think climate change should be for:

	Not a priority at all	Low priority	Medium priority	High priority	Very high priority
The President	○	○	○	○	○
Congress	○	○	○	○	○

****

11. Please write 1 to 3 short, simple sentences (about 30 words or less) that explain [*topics*: how scientists know that increasing greenhouse gases in the atmosphere are causing more frequent extreme weather events // how scientists know that increasing levels of CO_2 in the atmosphere is causing global warming // how global warming is happening // how scientists know that climate change influences our weather]. If you don't know, it's okay to say "I don't know."

[Open ended question – randomized topic will be assigned to each participant, and will match the topic of the essay that is read later; comparison group asked how global warming is occurring]

****

12. Please indicate how confident you are that the explanation you wrote in response to the previous question is correct.

- ❍ Not at all confident
- ❍ Slightly confident
- ❍ Somewhat confident
- ❍ Moderately confident
- ❍ Very confident

****

On the next page you will see a descriptive essay. Please read it carefully. Later you will be asked a few questions about it.

****

*Randomly assigned 1 of 13 short essays (1 = comparison group; 2-13 = either Science, Metaphor, or Science + Metaphor for one of 4 topics: frequency of extreme weather, increasing rate of CO2, enhanced greenhouse effect, and weather & climate***)**

*****Short essays have been uploaded as a separate document*****

****

13. Please rate the passage you just read on the following dimensions. Was it...?
[*Statements will be in randomized order*]

Helpful	○	○	○	○	○	○	○	Unhelpful
Interesting	○	○	○	○	○	○	○	Boring
Clear	○	○	○	○	○	○	○	Confusing
Trustworthy	○	○	○	○	○	○	○	Untrustworthy
Biased	○	○	○	○	○	○	○	Unbiased
Easy to understand	○	○	○	○	○	○	○	Difficult to understand

****

14. Thinking about what you just read, please write 1 to 3 short, simple sentences (about 30 words or less) that explain [how scientists know that increasing greenhouse gases in the atmosphere are causing more frequent extreme weather events // how scientists know that increasing levels of CO_2 in the atmosphere is causing global warming // how global warming is happening // how scientists know that climate change influences our weather].

[Open ended question – comparison group will *NOT* be asked]

****

15. Please indicate how confident you are that the explanation you wrote in response to the previous question is correct.
[Rate confidence in response / knowledge – comparison group will *NOT* be asked]

- Not at all confident
- Slightly confident
- Somewhat confident
- Moderately confident
- Very confident

****

16. Thinking back to what you read, please fill in the blank with a word or phrase. [Depending on what science topic was randomly assigned, participants would respond to a fill in the blank question; this question is *NOT* included for the comparison group]

Greenhouse gases, the _________ of the climate system, have become much more abundant over the past 250 years due to human activities. [Answer: steroids]

The ________ in the tub (or CO_2 in the atmosphere) is now rapidly rising, overflowing the tub, and we are observing the consequences (increasing global temperatures). [Answer: level of water; also accepted answer: water]

The burning of fossil fuels – coal, oil, and gas – have added layers to Earth's ______of heat trapping gases. [Answer: blanket]

Weather is much like your _______ in that it changes from day to day, and sometimes moment to moment. [Answer: mood]

****

17. What do you think: is climate change happening?

- Yes
- No
- Don't know

18a. ***If 'yes' to 3:*** How sure are you that climate change is happening?

- Extremely sure
- Very sure
- Somewhat sure
- Not sure at all

18b. ***If 'no' to 3:*** How sure are you that climate change is not happening?

- Extremely sure
- Very sure
- Somewhat sure
- Not sure at all

****

19. To the best of your knowledge, what proportion of global warming over the past several hundred years has been caused by human activity (versus natural changes in the environment)? Select "Not Applicable" if you don't believe there has been global warming over the past several hundred years.

20. How much do you trust or distrust scientists as a source of information about climate change?

- Strongly distrust
- Somewhat distrust
- Undecided
- Somewhat trust
- Strongly trust

21. When it comes to current affairs, people are very busy these days and many do not have time to follow what goes on in the government. Some do pay attention to politics but do not read questions carefully. To show that you've read this much, please ignore your real answer to the question below and instead select "slightly interested".

How interested are you in information about what's going on in government and politics?

- Extremely interested
- Very interested
- Moderately interested
- Slightly interested
- Not interested at all

****

22. How important is the issue of climate change to you personally?

- Not at all important
- Not too important
- Somewhat important
- Very important
- Extremely important

23. How big of an effort should the United States make to address climate change?

	No effort at all	A very large-scale effort
	0	100
Effort		

24. How much of a priority do you think climate change should be for:

	Not a priority at all	Low priority	Medium priority	High priority	Very high priority
The President	○	○	○	○	○
Congress	○	○	○	○	○

****

Lastly, we would like to ask a few questions about your background.

25. What is the highest level of education you have completed?

❍ Less than high school
❍ High school
❍ Some college
❍ Associate's degree
❍ Bachelor's degree
❍ Graduate degree

26. Are you Hispanic, Latino, or Spanish origin?

❍ Yes
❍ No
❍ I prefer not to answer

27. What is your race?

❍ White
❍ Black, African American
❍ American Indian, or Alaska Native
❍ Asian
❍ Pacific Islander
❍ Other
❍ I prefer not to say

28. What is your total annual household income, before taxes?

- ❍ $24,999 or less
- ❍ Between $25,000 and $49,999
- ❍ Between $50,000 and $74,999
- ❍ Between $75,000 and $99,999
- ❍ Between $100,000 and $124,999
- ❍ Between $125,000 and $149,999
- ❍ Between $150,000 and $174,999
- ❍ $175,000 or more

29. In general, I think of myself as…

- ❍ Very conservative
- ❍ Conservative
- ❍ Somewhat conservative
- ❍ Moderate, middle of the road
- ❍ Somewhat liberal
- ❍ Liberal
- ❍ Very Liberal

C.2 – Stimulus Materials

Comparison group message condition essay

Will Juno reveal some of Jupiter's secrets?

In Greek and Roman mythology, Jupiter drew a veil of clouds around himself to hide his mischief. It was Jupiter's wife, the goddess Juno, who was able to peer through the clouds and reveal Jupiter's true nature. NASA's Juno spacecraft will also allow scientists and other observers to look beneath the clouds to see what it's up to. Though this mission is not seeking signs of misbehavior on Jupiter, they are seeking clues for us to understand the planet's structure and history.

Juno is the second probe in NASA's New Frontiers Program. The spacecraft began collecting data on July 5th after a 59-month journey to Jupiter – the mission was launched on August 5, 2011 from Cape Canaveral. Scientists are hoping they will uncover many of Jupiter's and the solar system's secrets during the mission as observations to date of Jupiter have come from only a few spacecraft. For example, the Galileo spacecraft sent a descent probe to collect data on Jupiter's atmosphere; and the New Horizons spacecraft captured a magnificent outburst of a volcano on Jupiter's moon, Io, on its way to Pluto. Now with Juno, scientists are looking to better understand Jupiter's atmosphere and its water content; the magnetic and gravity fields present; and how the magnetic environment affects the atmosphere. Simply put, the mission's scientists are investigating what is in and beneath the clouds on this massive planet, and what it can tell us about how our Earth and other planets came to be.

Equipped with eight primary scientific instruments, 29 sensors, and the ability to generate its electrical needs from a large solar cell array, the probe will complete 37 orbits of the gigantic gas planet in 18 months. The small but steady source of energy has allowed Juno not only to venture into space so far away from the sun, but also last through the mission end date. It officially set the record for a solar powered spacecraft travelling into deep space in January when it reached a distance of approximately 493 million miles from the sun (previous record was set by the European Space Agency's Rosetta spacecraft). Another integral and incredible feature of Juno is a first of its kind: a shielded vault to protect the probe's electronics from Jupiter's heavy radiation environment. This feature is very important because Jupiter's magnetic field is about 20,000 times Earth's which accelerates charged particles near Jupiter to enormously high velocities. This vault allows Juno's instrumentation to withstand almost constant bombardment by these charged particles moving at super fast speeds.

Juno will have a rather dramatic death at the mission's conclusion in February 2018. A five and a half day maneuver will intentionally crash the probe into Jupiter's thick hydrogen and helium filled atmosphere. In the meantime, Juno will be mapping Jupiter's magnetic and gravity fields as well as measuring atmospheric ammonia, water and other substances. From this data we will be able to cast further light on the planet's formation and evolutionary history in addition to determining if the center is solid much like Earth's.

Frequency of extreme weather events essays

Science + Metaphor

How do we know that an increase in greenhouse gases is causing more frequent extreme weather events?

A recent report by over 300 leading American climate scientists reached the following conclusion: *Some types of extreme weather and climate events have increased in the United States, and worldwide, over the past 50 years, and these increases are related to human-caused global warming.* How do scientists know that extreme weather events are occurring more frequently than in the past due to human activities?

First, let's think about a similar question: How do we know if the frequency of homerun hits in Major League Baseball (MLB) is due to players taking steroids? We can look at the data. For example, by comparing the frequency of homeruns hit each year in the league before and after steroid use became common among MLB players, we can estimate how much of the increased frequency in homeruns is due to steroid use. This method is similar to how climate scientists assess the impact of heat-trapping greenhouse gases – including carbon dioxide – from the burning of fossil fuels on the frequency of extreme weather events. They have examined historical data on both extreme weather events and the amount of greenhouse gases in the atmosphere over a long period of time. Greenhouse gases, the steroids of the climate system, have become much more abundant over the past 250 years due to human activities. These measurements allow scientists to determine how much greenhouse gases have contributed to the strength and frequency of extreme weather events.

Since the industrial revolution started around 1750, large amounts of fossil fuels – coal, oil, and gas – have been burned for electricity and transportation. This has released large amounts of carbon dioxide and other heat-trapping greenhouse gases which accumulate in the atmosphere. The consequence is that Earth has gotten warmer, especially over the past century. During this time, there have been increases in the frequency and severity of heat waves and heavy downpours across the United States. Many regions of the country have also had increases in severe floods, droughts, and extreme winter storms. One recent example is the more extreme El Niño weather patterns than we have experienced in the past.

Climate scientists have rigorous methods to determine historical average temperatures, rainfall amounts, and levels of greenhouse gases in the atmosphere over the past 100,000 years and more. By comparing data collected over the last 100 years to the older historical data, scientists have shown that extreme weather events have become more frequent. Using computer models and simulations to conduct experiments, scientists have concluded that extreme weather events would not have become more frequent if levels of greenhouse gases in our atmosphere had not increased over the past 250 years.

The important point to remember is that the accumulation of heat-trapping greenhouse gases from human activities in the Earth's atmosphere is increasing the frequency and severity of some categories of extreme weather and climate events in the United States.

Science Only

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Climate scientists have rigorous methods to determine historical average temperatures, rainfall amounts, and levels of greenhouse gases in the atmosphere over the past 100,000 years and more. By comparing data collected over the last 100 years to the older historical data, scientists have shown that extreme weather events have become more frequent. Using computer models and simulations to conduct experiments, scientists have concluded that extreme weather events would not have become more frequent if levels of greenhouse gases in our atmosphere had not increased over the past 250 years.

The important point to remember is that the accumulation of heat-trapping greenhouse gases from human activities in the Earth's atmosphere is increasing the frequency and severity of some kinds of extreme weather events in the United States.

Metaphor Only

How do we know that an increase in greenhouse gases is causing more frequent extreme weather events?

A recent report by over 300 leading American climate scientists reached the following conclusion: *Some types of extreme weather and climate events have increased in the United States, and worldwide, over the past 50 years, and these increases are related to human-caused global warming.* How do scientists know that extreme weather events are occurring more frequently than in the past due to human activities?

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The important point to remember is that the accumulation of heat-trapping greenhouse gases from human activities in the Earth's atmosphere is increasing the frequency and severity of some categories of extreme weather and climate events in the United States.

Increasing carbon dioxide in the atmosphere essays

Science + Metaphor

How do we know that increasing levels of CO_2 in the atmosphere is causing global warming?

Scientists have been measuring and tracking carbon dioxide (CO_2), a heat-trapping gas, at the Mauna Loa Observatory in Hawaii since 1958. At the time, CO_2 levels were at 315 parts per million (ppm). The level of CO_2 reached a milestone in 2013, 400 ppm, and is still steadily rising. The rate of CO_2 increase we are observing now is approximately 100 times faster than at the end of the last Ice Age, when CO_2 levels were much lower than today. This is causing the Earth to warm. Where is this CO_2 coming from, and how do scientists know that the extra CO_2 is causing the earth to warm?

To answer this question, let's first think of the atmosphere as a bathtub. The amount of water flowing into the tub through the faucet represents the CO_2 that is naturally released into the atmosphere. The amount of water leaving the tub through the drain represents the amount of CO_2 that plants capture and deposit in the soil. The amount of CO_2 flowing in and draining out has been balanced for a long period of time providing a habitable environment. Now however, because of human activities more water is flowing from the tap and the drain is smaller. Over the past 100 years, the burning of fossil fuels – coal, oil, and gas – has dramatically increased the rate of flow into the atmosphere. Deforestation has also dramatically decreased the rate of flow out. Therefore, the level of water in the tub (or CO_2 in the atmosphere) is now rapidly rising, overflowing the tub, and we are observing the consequences (increasing global temperatures).

All of the Earth's carbon is stored in one of four places: the atmosphere, the oceans, the soil, and deep underground. Over the past several million years, the ratio of carbon has shifted between these places. When the balance of carbon has shifted from the soil and underground to the atmosphere and the oceans, the Earth has warmed. This has occurred when carbon dioxide levels were at about 300 ppm or higher in the atmosphere. This resulted in altering weather patterns and melting sea and land surface ice. When the shift went in the other direction, from the atmosphere and oceans into the soil and underground, the Earth cooled and atmospheric CO_2 was lower, about 200 ppm. This has been associated with past ice ages. Over the past 100 years or so, the burning of fossil fuels and deforestation has significantly changed where carbon is stored. Fossil fuels store carbon deep underground and release CO_2 into the atmosphere when burned which plants and the soil cannot absorb at the same rate that it is released.

The important point to remember is that there is an increasing accumulation of heat-trapping greenhouse gases in the Earth's atmosphere as a result of human activities. When CO_2 concentration goes up, temperature goes up.

Science Only

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Enhanced greenhouse effect essays

Science + Metaphor

How Does Climate Change (or "Global Warming") Work?

Scientists tell us that human activities are changing Earth's atmosphere and increasing Earth's average temperature. What causes these climatic changes?

To understand this better, first let's look at how heat-trapping greenhouse gases like carbon dioxide and methane act as a blanket. When we go to bed at night, we cover ourselves with layers of blankets to keep warm. Our bodies radiate heat, which is absorbed by the blankets keeping us comfortably warm as we sleep. If we go to bed with too many blankets, we will become uncomfortably warm. This is similar to Earth's natural atmospheric blanket of greenhouse gases, except in one important way. The Earth's atmospheric blanket doesn't interfere with the sun's energy passing through to Earth, which is mostly visible light. However, it does interfere with Earth's energy as it escapes back out into space as infrared energy. The burning of fossil fuels – coal, oil, and gas – have added layers to Earth's blanket of heat trapping gases. This has caused the Earth to get hotter and hotter, and has changed the climate and weather we experience today.

Let's now look at how Earth's "normal" temperature works. The sun emits energy in the form of sunlight. When Earth absorbs sunlight, which is mostly visible light, it heats up. Like the sun, Earth also emits energy – but because it is cooler than the sun, Earth emits lower-energy called infrared energy. This infrared energy returns heat back to space. In fact, the infrared energy returning to space is the only way Earth can lose heat. Greenhouse gases in the atmosphere, like carbon dioxide and methane, let visible light pass through but also absorbs infrared energy causing the atmosphere to heat up. As a result, Earth is warm enough to support life as we know it. (In contrast, the moon has no atmosphere, and it is colder than Earth, on average.)

Since the industrial age began around 1750, carbon dioxide in the atmosphere has increased by 40% and methane has increased by 150% mainly due to the burning of fossil fuels. These increases cause extra infrared energy absorption, further heating Earth above its typical temperature range (even as energy from the sun stays basically the same). In other words, energy that reaches Earth has an even harder time leaving it, causing Earth's average temperature to increase— producing global warming and climate change.

In summary: (a) Earth absorbs most of the sunlight it receives; (b) Earth then emits the absorbed light's energy as infrared energy; (c) greenhouse gases absorb a lot of the infrared energy before it can leave our atmosphere; (d) being absorbed slows the rate at which energy escapes to space; and (e) the slower passage of energy heats up the atmosphere, water, and ground.

By increasing the amount of greenhouse gases in the atmosphere, humans are increasing the atmosphere's absorption of infrared light, thereby warming Earth and disrupting global climate patterns.

Science Only

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Weather, climate and climate change essays

Science + Metaphor

How do we know that climate change influences our weather?

The saying goes: climate is what you expect and weather is what you get. With climate change however, it is more complicated than that. How does understanding the relationship between weather and climate help scientists understand how climate change is influencing our weather?

To understand this relationship between weather and climate, consider your own moods and personality. Weather is much like your mood in that it changes from day to day, and sometimes moment to moment. In contrast, your personality is relatively constant; it is made up of numerous traits and is the foundation of who you are. Climate is much like your personality in that it is relatively stable.

Our moods vary and some strong moods last for a day or even weeks, but eventually our personality takes over and we return to our normal pattern of moods. For most of us, our personality remains relatively stable throughout our lifetime. Occasionally an extreme expression of a mood can be elicited due to a particular situation, and in some cases may be more permanent due to a serious brain injury or brain tumor. Just as a serious brain injury or brain tumor may chronically change one's personality, accumulating greenhouse gases in the atmosphere are changing our climate and is having a lasting impact on our weather patterns.

Let's understand what weather and climate are more deeply. Weather is the condition of the atmosphere at a particular time and place, and can change frequently from day to day, or sometimes in just a few minutes. Factors that drive weather are storm systems, warm and cold fronts, and the cycle of day and night. Climate is the average of weather conditions in a particular place over a long period of time, typically 30 years. The climate in a particular place, and especially the climate of the Earth overall, is usually consistent over a human lifetime. Climate is defined by factors that change slowly (average temperature and precipitation); and factors that haven't changed in a very long time (a location's latitude and elevation, bodies of water, ocean currents, and type of vegetation). Temperature and precipitation in particular can be affected by the abundance of greenhouse gases in the atmosphere and result in a change in weather patterns.

To predict weather and climate, very similar models are used that incorporate the many different factors. These models though, differ in space and time. Weather forecast models, for example make accurate predictions for up to seven days and for a specific place, or your local region. Climate models make projections for much larger regions, and on longer timescales – even up to 100 years into the future.

Research by climatologists have provided evidence that increasing levels of heat-trapping greenhouse gases in our atmosphere are warming our planet and changing our weather. Will we continue to occasionally have unusually cold winters, and mild summers? We will, but on average our winters and summers are projected to continue to get warmer, which will continue to change our weather patterns in a number of ways.

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REFERENCES

Ait El Houssi, A., Morel, K. P., & Hultink, E. J. (2004). Effectively communicating new product benefits to consumers: the use of analogy versus literal similarity.

Anderson, A. A., Myers, T. A., Maibach, E. W., Cullen, H., Gandy, J., Witte, J., . . . Leiserowitz, A. (2013). If They Like You, They Learn from You: How a Brief Weathercaster-Delivered Climate Education Segment Is Moderated by Viewer Evaluations of the Weathercaster. *Weather, Climate, and Society, 5*(4), 367-377. doi:10.1175/WCAS-D-12-00051.1

Anderson, K., & Bows, A. (2012). A new paradigm for climate change. *Nature Climate Change, 2*(9), 639-640.

Atanasova, D., & Koteyko, N. (2015). Metaphors in Guardian Online and Mail Online Opinion-page Content on Climate Change: War, Religion, and Politics. *Environmental Communication*, 1-18. doi:10.1080/17524032.2015.1024705

Aubusson, P. J., Harrison, A. G., & Ritchie, S. M. (2006). Metaphor and Analogy. In P. J. Aubusson, A. G. Harrison, & S. M. Ritchie (Eds.), *Metaphor and Analogy in Science Education* (Vol. 30). Dorderecht, The Netherlands: Springer.

Ausubel, D. P. (1960). The use of advance organizers in the learning and retention of meaningful verbal material. *Journal of Educational Psychology, 51*(5), 267-272.

Berinsky, A. J., Huber, G. A., & Lenz, G. S. (2012). Evaluating online labor markets for experimental research: Amazon. com's Mechanical Turk. *Political Analysis, 20*(3), 351-368.

Bettman, J. R., & Park, C. W. (1980). Effects of Prior Knowledge and Experience and Phase of the Choice Process on Consumer Decision Processes: A Protocol Analysis. *Journal of Consumer Research, 7*(3), 234-248. doi:10.2307/2489009

Blasko, D. G., & Connine, C. M. (1993). Effects of familiarity and aptness on metaphor processing. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*(2), 295-308. doi:10.1037/0278-7393.19.2.295

Blockstein, D. E. (2002). How to lose your political virginity while keeping your scientific credibility. *BioScience, 52*(1), 91-96.

Boozer, R. W., Wyld, D. C., & Grant, J. (1990). Using Metaphor to Create More Effective Sales Messages. *Journal of Services Marketing, 4*(3), 63-71. doi:doi:10.1108/EUM0000000002520

Bosman, J. (1987). Persuasive Effects of Political Metaphors. *Metaphor and Symbolic Activity, 2*(2), 97-113. doi:10.1207/s15327868ms0202_2

Bosman, J., & Hagendoorn, L. (1991). Effects of Literal and Metaphorical Persuasive Messages. *Metaphor and Symbolic Activity, 6*(4), 271-292. doi:10.1207/s15327868ms0604_3

Bostrom, A., Morgan, M. G., Fischhoff, B., & Read, D. (1994). What Do People Know About Global Climate Change? 1. Mental Models. *Risk Analysis, 14*(6), 959-970. doi:10.1111/j.1539-6924.1994.tb00065.x

Boykoff, M. T., & Boykoff, J. M. (2007). Climate change and journalistic norms: A case-study of US mass-media coverage. *Geoforum, 38*(6), 1190-1204. doi:http://dx.doi.org/10.1016/j.geoforum.2007.01.008

Brown, T. L. (2003). *Making Truth: Metaphor in Science*. Chicago: University of Illinois Press.

Cash, D. W., Borck, J. C., & Patt, A. G. (2006). Countering the loading-dock approach to linking science and decision making comparative analysis of El Niño/Southern Oscillation (ENSO) Forecasting Systems. *Science, Technology & Human Values, 31*(4), 465-494.

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., . . . Mitchell, R. B. (2003). Knowledge systems for sustainable development. *Proceedings of the National Academy of Sciences, 100*(14), 8086-8091.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Thousand Oaks, CA: Sage Publications.

Clark, W. C., Mitchell, R. B., & Cash, D. W. (2006). Evaluating the Influence of Global Environmental Assessments. *Global environmental assessments: information and influence*.

U.S. Global Change Research Act of 1990, § 104, 203 (1990).

Cook, J., Oreskes, N., Doran, P., Anderegg, W. R. L., Verheggen, B., Maibach, E., . . . Rice, K. (2016). Consensus on consensus: a synthesis of consensus estimates on human-caused global warming. *Environmental Research Letters, 11*(4), 048002.

Cooke, R. M., & Goossens, L. H. (2004). Expert judgement elicitation for risk assessments of critical infrastructures. *Journal of Risk Research, 7*(6), 643-656.

Dabelko, G. D. (2005). Speaking their language: how to communicate better with policymakers and opinion shapers–and why academics should bother in the first place. *International Environmental Agreements: Politics, Law and Economics, 5*(4), 381-386.

Davidson, R. E. (1976). The role of metaphor and analogy in learning. In J. R. Levin & V. L. Allen (Eds.), *Cognitive learning in children* (pp. 135-162). New York: AcademicPress.

Dilling, L., & Lemos, M. C. (2011). Creating usable science: Opportunities and constraints for climate knowledge use and their implications for science policy. *Global Environmental Change, 21*(2), 680-689.

Doria, M. d. F., Boyd, E., Tompkins, E. L., & Adger, W. N. (2009). Using expert elicitation to define successful adaptation to climate change. *Environmental Science & Policy, 12*(7), 810-819. doi:http://dx.doi.org/10.1016/j.envsci.2009.04.001

Dryzek, J. S. (2010). Rhetoric in Democracy: A Systemic Appreciation. *Political Theory, 38*(3), 319-339. doi:10.1177/0090591709359596

Dryzek, J. S., & Lo, A. Y. (2015). Reason and rhetoric in climate communication. *Environmental Politics, 24*(1), 1-16. doi:10.1080/09644016.2014.961273

Duit, R., & Glynn, S. (1996). Mental modelling. In G. Welford, J. Osborne, & P. Scott (Eds.), *Research in Science Education in Europe* (pp. 166-176). Washington D.C.: The Falmer Press.

Edmonds, B. (1995). What is Complexity? - The philosophy of complexity per se with application to some examples in evolution. In F. Heylighen & D. Aerts (Eds.), *The Evolution of Complexity*: Kluwer, Dordrecht.

Epstein, S., & Pacini, R. (1999). Some Basic Issues Regarding Dual-Processing Theories from the Perspective of Cognitive-Experiential Self-Theory. In S. Chaiken & Y. Trope (Eds.), *Dual-process Theories in Social Psychology*. New York: The Guilford Press.

Epstein, S., Pacini, R., Denes-Raj, V., & Heier, H. (1996). Individual differences in intuitive–experiential and analytical–rational thinking styles. *Journal of Personality and Social Psychology, 71*(2).

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*(2), 175-191.

Feiereisen, S., Wong, V., & Broderick, A. J. (2008). Analogies and Mental Simulations in Learning for Really New Products: The Role of Visual Attention. *Journal of Product Innovation Management, 25*(6), 593-607. doi:10.1111/j.1540-5885.2008.00324.x

Feldman, D. L., & Ingram, H. M. (2009). Making science useful to decision makers: climate forecasts, water management, and knowledge networks. *Weather, Climate, and Society, 1*(1), 9-21.

Fischhoff, B., Slovic, P., & Lichtenstein, S. (1982). Lay Foibles and Expert Fables in Judgments about Risk. *The American Statistician, 36*(3b), 240-255. doi:10.1080/00031305.1982.10482845

Fiske, S. T., & Dupree, C. (2014). Gaining trust as well as respect in communicating to motivated audiences about science topics. *Proceedings of the National Academy of Sciences, 111*(Supplement 4), 13593-13597. doi:10.1073/pnas.1317505111

Galesic, M., & Garcia-Retamero, R. (2013). Using Analogies to Communicate Information about Health Risks. *Applied Cognitive Psychology, 27*(1), 33-42. doi:10.1002/acp.2866

Gallois, C., Ogay, T., & Giles, H. (2005). Communication accommodation theory: A look back and a look ahead. In W. Gudykunst (Ed.), *Theorizing about intercultural communication* (pp. 121-148). Thousand Oaks, Ca: Sage.

Gentner, D. (1983). Structure-mapping: A theoretical framework for analogy. *Cognitive Science, 7*(2), 155-170. doi:10.1016/S0364-0213(83)80009-3

Gentner, D., & Bowdle, B. F. (2001). Convention, Form, and Figurative Language Processing. *Metaphor and Symbol, 16*(3-4), 223-247. doi:10.1080/10926488.2001.9678896

Gentner, D., Holyoak, K. J., & Kokinov, B. N. (2001). *The analogical mind: perspectives from cognitive science*: MIT Press.

Gentner, D., & Markman, A. B. (1997). Structure mapping in analogy and similarity. *American Psychologist, 52*(1), 45-56. doi:10.1037/0003-066X.52.1.45

Gibbs, R. (1987). What does it mean to say that a metaphor has been understood? In R. E. Haskell (Ed.), *Cognition and Symbolic Structures.* Norwood, NJ: Ablex Publishing Corporation.

Glynn, S. M. (1991). Explaining science concepts: A teaching-with-analogies model. In S. Glynn, R. Yeanny, & B. Britton (Eds.), *The psychology of learning science* (pp. 219-240).

Glynn, S. M., & Takahashi, T. (1998). Learning from analogy-enhanced science text. *Journal of Research in Science Teaching, 35*(10), 1129-1149. doi:10.1002/(SICI)1098-2736(199812)35:10<1129::AID-TEA5>3.0.CO;2-2

Graesser, A. C., Mio, J. S., & Millis, K. K. (1989). Metaphors in persuasive communication. In D. Meutsch & R. Viehoff (Eds.), *Comprehension of literary discourse: Results and problems of interdisciplinary approaches* (pp. 131-154). Berlin, Germany: Walter de Gruyter.

Guerra-Ramos, M. T. (2011). Analogies as Tools for Meaning Making in Elementary Science Education: How Do They Work in Classroom Settings? *Eurasia Journal of Mathematics, Science & Technology Education, 7*(1), 29-39.

Gülich, E. (2003). Conversational Techniques Used in Transferring Knowledge between Medical Experts and Non-experts. *Discourse Studies, 5*(2), 235-263. doi:10.1177/14614456030050020005

Guston, D. H. (2001). Boundary Organizations in Environmental Policy and Science: An Introduction. *Science, Technology, & Human Values, 26*(4), 399-408. doi:10.2307/690161

Guy, S., Kashima, Y., Walker, I., & O'Neill, S. (2014). Investigating the effects of knowledge and ideology on climate change beliefs. *European Journal of Social Psychology, 44*(5), 421-429. doi:10.1002/ejsp.2039

Guy, S., Kashima, Y., Walker, I., & O'Neill, S. (2013). Comparing the atmosphere to a bathtub: effectiveness of analogy for reasoning about accumulation. *Climatic Change, 121*(4), 579-594. doi:10.1007/s10584-013-0949-3

Hagerman, S., Dowlatabadi, H., Satterfield, T., & McDaniels, T. (2010). Expert views on biodiversity conservation in an era of climate change. *Global Environmental Change, 20*(1), 192-207. doi:http://dx.doi.org/10.1016/j.gloenvcha.2009.10.005

Hahn, T., Olsson, P., Folke, C., & Johansson, K. (2006). Trust-building, knowledge generation and organizational innovations: the role of a bridging organization for adaptive comanagement of a wetland landscape around Kristianstad, Sweden. *Human ecology, 34*(4), 573-592.

Halpern, D. F., Hansen, C., & Riefer, D. (1990). Analogies as an aid to understanding and memory. *Journal of Educational Psychology, 82*(2), 298-305. doi:10.1037/0022-0663.82.2.298

Hamill, R., Wilson, T. D., & Nisbett, R. E. (1980). Insensitivity to sample bias: Generalizing from atypical cases. *Journal of Personality and Social Psychology, 39*(4).

Hansen, J. (2007). Scientific reticence and sea level rise. *Environmental Research Letters, 2*(2).

Hansen, J. W., Marx, S. M., & Weber, E. U. (2004). The Role of Climate Perceptions, Expectations, and Forecasts in Farmer Decision Making: The Argentine Pampas and South Florida: Final Report of an IRI Seed Grant Project.
Harrington, K. J. (2012). The Use of Metaphor in Discourse About Cancer: A Review of the Literature. *Clinical Journal of Oncology Nursing, 16*(4), 408-412.
Hassol, S. J. (2008). Improving How Scientists Communicate About Climate Change. *Eos, Transactions American Geophysical Union, 89*(11), 106-107. doi:10.1029/2008EO110002
Hoeffler, S., & Herzenstein, M. (2011). Optimal Marketing for Really New Products: Using a Consumer Perspective to Improve Communications. In S. Posavac (Ed.), *Cracking the Code: Leveraging Consumer Psychology to Drive Profitability* (pp. 21-44). New York: Routledge.
Holyoak, K., Gentner, D., & Kokinov, B. (2001). The place of analogy in cognition. In K. Holyoak, D. Gentner, & B. Kokinov (Eds.), *The analogical mind: Perspectives from cognitive science* (pp. 1-19).
Hulme, M. (2012). What sorts of knowledge for what sort of politics? Science, climate change and the challenge of democracy 3S Working Paper 2012-15 (Norwich: Science, Society and Sustainability Research Group).
Ivie, S. D. (1998). Ausubel's Learning Theory: An Approach to Teaching Higher Order Thinking Skills. *The High School Journal, 82*(1), 35-42. doi:10.2307/40364708
Jasanoff, S. (1986). *Risk management and political culture: a comparative study of science in the policy context* (Vol. 12): Russell Sage Foundation.
Jasanoff, S. S. (1986). *Risk management and political culture: a comparative study of science in the policy context* (Vol. 12): Russell Sage Foundation.
Kahan, D. (2013). What's a valid sample: Problems with mechanical turk study samples, part 1. Retrieved from http://www.culturalcognition.net/blog/2013/7/8/whats-a-valid-sample-problems-with-mechanical-turk-study-sam.html
Kahneman, D. (2011). *Thinking, Fast and Slow*. New York, New York: Farrar, Straus and Gliroux.
Kazmerski, V., Blasko, D., & Dessalegn, B. (2003). ERP and behavioral evidence of individual differences in metaphor comprehension. *Memory & Cognition, 31*(5), 673-689. doi:10.3758/BF03196107
Kendall-Taylor, N., Erard, M., & Haydon, A. (2013). The Use of Metaphor as a Science Communication Tool: Air Traffic Control for Your Brain. *Journal of Applied Communication Research, 41*(4), 412-433. doi:10.1080/00909882.2013.836678
Krayer von Krauss, M. P., Casman, E. A., & Small, M. J. (2004). Elicitation of Expert Judgments of Uncertainty in the Risk Assessment of Herbicide-Tolerant Oilseed Crops. *Risk Analysis, 24*(6), 1515-1527.
Krieger, J. L., Parrott, R. L., & Nussbaum, J. F. (2010). Metaphor Use and Health Literacy: A Pilot Study of Strategies to Explain Randomization in Cancer Clinical Trials. *Journal of health communication, 16*(1), 3-16. doi:10.1080/10810730.2010.529494
Kuypers, J. A. (2009). Framing Analysis. In J. A. Kuyper (Ed.), *Rhetorical criticism: perspectives in action* (pp. 181-204). Lanham, MD: Lexington Books.

Lakoff, G. (1993). The contemporary theory of metaphor. In A. Ortony (Ed.), *Metaphor and thought* (Vol. 2, pp. 202-251).
Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago: University of Chicago Press.
Lakoff, G., & Johnson, M. (2003). *Metaphors we live by* (2nd ed.). Chicago: University of Chicago Press.
Leeper, T., & Mullinix, K. J. (2014). What if you had done things differently? Testing the generalizability of framing effects with parallel experiments. *Unpublished manuscript*.
Leiserowitz, A., Maibach, E., Roser-Renouf, C., Feinberg, G., & Howe, P. (2012). Climate change in the American mind: Americans' global warming beliefs and attitudes in September, 2012. *Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change*.
Leiserowitz, A., Maibach, E., Roser-Renouf, C., Feinberg, G., & Rosenthal, S. (2015). *Climate Change in the American mind: March, 2015*. Retrieved from New Haven, CT:
Leiserowitz, A., Maibach, E., Roser-Renouf, C., Smith, N., & Hmielowski, J. D. (2011). Climate change in the American Mind: Americans' global warming beliefs and attitudes in November 2011: Yale University and George Mason University.
Leiserowitz, A., & Smith, N. (2010). Knowledge of climate change across global warming's six Americas. *Yale University, New Haven CT: Yale Project on Climate Change Communication. Available at environment. yale. edu/climate/files/Knowledge_Across_Six_Americas. pdf.*
Leiserowitz, A., Smith, N., & Marlon, J. R. (2010). *Americans' Knowledge of Climate Change*. Retrieved from http://environment.yale.edu/climate-communication/files/ClimateChangeKnowledge2010.pdf
Lemos, M. C., Kirchhoff, C. J., & Ramprasad, V. (2012). Narrowing the climate information usability gap. *Nature Climate Change, 2*(11), 789-794.
Lemos, M. C., & Morehouse, B. J. (2005). The co-production of science and policy in integrated climate assessments. *Global Environmental Change, 15*(1), 57-68.
Lemos, M. C., & Rood, R. B. (2010). Climate projections and their impact on policy and practice. *Wiley Interdisciplinary Reviews: Climate Change, 1*(5), 670-682.
Lindland, E. H., & Kendall-Taylor, N. (2012). Sensical Translations: Three Case Studies in Applied Cognitive Communications. *Annals of Anthropological Practice, 36*(1), 45-67. doi:10.1111/j.2153-9588.2012.01092.x
Loewenstein, G. F., Weber, E. U., Hsee, C. K., & Welch, N. (2001). Risk as feelings. *Psychological Bulletin, 127*(2).
Lombardi, D., & Sinatra, G. M. (2012). College Students' Perceptions About the Plausibility of Human-Induced Climate Change. *Research in Science Education, 42*(2), 201-217. doi:10.1007/s11165-010-9196-z
Lowe, T. D., & Lorenzoni, I. (2007). Danger is all around: Eliciting expert perceptions for managing climate change through a mental models approach. *Global Environmental Change, 17*(1), 131-146. doi:http://dx.doi.org/10.1016/j.gloenvcha.2006.05.001

Lupia, A. (2013). Communicating science in politicized environments. *Proceedings of the National Academy of Sciences, 110*(Supplement 3), 14048-14054. doi:10.1073/pnas.1212726110
Maibach, E. W., Nisbet, M., Baldwin, P., Akerlof, K., & Diao, G. (2010). Reframing climate change as a public health issue: an exploratory study of public reactions. *BMC Public Health, 10*(1), 1-11. doi:10.1186/1471-2458-10-299
Marx, S. M., Weber, E. U., Orlove, B. S., Leiserowitz, A., Krantz, D. H., Roncoli, C., & Phillips, J. (2007). Communication and mental processes: Experiential and analytic processing of uncertain climate information. *Global Environmental Change, 17*(1), 47-58.
Mason, L. (1994). Analogy, Metaconceptual Awareness and Conceptual Change: a classroom study. *Educational Studies, 20*(2), 267-291. doi:10.1080/0305569940200209
Mayer, R. E. (1979). Can Advance Organizers Influence Meaningful Learning? *Review of Educational Research, 49*(2), 371-383. doi:10.2307/1169964
Mayer, R. E. (1993). The instructive metaphor: Metaphoric aids to students' understanding of science. In A. Ortony (Ed.), *Metaphor and thought*. New York: Cambridge University Press.
Mayer, R. E., & Bromage, B. K. (1980). Difference recall protocols for technical texts due to advance organizers. *Journal of Educational Psychology, 72*(2), 209-225.
Mayer, R. E., Dyck, J. L., & Cook, L. K. (1984). Techniques that help readers build mental models from scientific text: Definitions pretraining and signaling. *Journal of Educational Psychology, 76*(6), 1089-1105. doi:10.1037/0022-0663.76.6.1089
McClure, J. R., Sonak, B., & Suen, H. K. (1999). Concept map assessment of classroom learning: Reliability, validity, and logistical practicality. *Journal of Research in Science Teaching, 36*(4), 475-492. doi:10.1002/(SICI)1098-2736(199904)36:4<475::AID-TEA5>3.0.CO;2-O
McCroskey, J. C., & Combs, W. H. (1969). The Effects of the Use of Analogy on Attitude Change and Source Credibility. *Journal of Communication, 19*(4), 333-339. doi:10.1111/j.1460-2466.1969.tb00856.x
McGlone, M. S. (2007). What is the explanatory value of a conceptual metaphor? *Language & Communication, 27*(2), 109-126. doi:http://dx.doi.org/10.1016/j.langcom.2006.02.016
McNie, E. C. (2007). Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environmental Science & Policy, 10*(1), 17-38.
Mio, J. S. (1997). Metaphor and Politics. *Metaphor and Symbol, 12*(2), 113-133. doi:10.1207/s15327868ms1202_2
Morgan, M. G., Fischhoff, B., Bostrom, A., & Atman, C. J. (2002). *Risk Communication A Mental Models Approach*: Cambridge University Press.
Morgan, M. G., Henrion, M., & Small, M. (1992). *Uncertainty: a guide to dealing with uncertainty in quantitative risk and policy analysis*: Cambridge university press.

Morgan, M. G., Pitelka, L. F., & Shevliakova, E. (2001). Elicitation of Expert Judgments of Climate Change Impacts on Forest Ecosystems. *Climatic Change, 49*(3), 279-307. doi:10.1023/a:1010651300697

Moser, S. C. (2010). Now more than ever: The need for more societally relevant research on vulnerability and adaptation to climate change. *Applied Geography, 30*(4), 464-474. doi:http://dx.doi.org/10.1016/j.apgeog.2009.09.003

Nagda, B. R. A. (2006). Breaking barriers, crossing borders, building bridges: Communication processes in intergroup dialogues. *Journal of Social Issues, 62*(3), 553-576.

National Research Council. (2009). *Informing Decisions in a Changing Climate*. Washington, D.C.: National Academies Press.

National Research Council Committee on Risk Perception and Communication. (1989). *Improving Risk Communication*. Washington, DC: National Academy Press.

Nelkin, D. (1995). *Selling science: How the press covers science and technology*: WH Freeman New York.

Niebert, K., & Gropengiesser, H. (2012). Understanding and communicating climate change in metaphors. *Environmental Education Research*(ahead-of-print), 1-21.

Nordhaus, W. D. (1994). Expert opinion on climatic change. *American Scientist, 82*(1), 45-51.

Novak, J. D. (1980). Learning Theory Applied to the Biology Classroom. *The American Biology Teacher, 42*(5), 280-285. doi:10.2307/4446939

Novak, J. D., Bob Gowin, D., & Johansen, G. T. (1983). The use of concept mapping and knowledge vee mapping with junior high school science students. *Science Education, 67*(5), 625-645. doi:10.1002/sce.3730670511

O'Keefe, D. (2002). *Persuasion Theory and Research* (2nd ed.): Sage Publications.

Ockwell, D., Whitmarsh, L., & O'Neill, S. (2009). Reorienting climate change communication for effective mitigation: forcing people to be green or fostering grass-roots engagement? *Science Communication*.

Ortony, A. (1975). Why Metaphors Are Necessary and Not Just Nice1. *Educational Theory, 25*(1), 45-53. doi:10.1111/j.1741-5446.1975.tb00666.x

Ottati, V. C., & Renstrom, R. A. (2010). Metaphor and Persuasive Communication: A Multifunctional Approach. *Social and Personality Psychology Compass, 4*(9), 783-794. doi:10.1111/j.1751-9004.2010.00292.x

Ottati, V. C., Rhoads, S., & Graesser, A. C. (1999). The effect of metaphor on processing style in a persuasion task: A motivational resonance model. *Journal of Personality and Social Psychology, 77*(4), 688-697. doi:10.1037/0022-3514.77.4.688

Pagano, T. C., Hartmann, H. C., & Sorooshian, S. (2001). Using Climate Forecasts for Water Management: Arizona and the 1997-1998 El Nino. *JAWRA Journal of the American Water Resources Association, 37*(5), 1139-1153.

Petty, R. E. (1997). The evolution of theory and research in social psychology: From single to multiple effect and process models of persuasion. In C. McGarty & S. A. Haslam (Eds.), *The Message of Social Psychology: Perspectives on Mind in Society* (pp. 268–290): Blackwell Publishers Ltd.

Pidgeon, N., & Fischhoff, B. (2011). The role of social and decision sciences in communicating uncertain climate risks. *Nature Climate Change, 1*(1), 35-41.

Power, S., Sadler, B., & Nicholls, N. (2005). The influence of climate science on water management in western Australia: Lessons for climate scientists. *Bulletin of the American Meteorological Society, 86*(6), 839-844.

Pulwarty, R. S., & Melis, T. S. (2001). Climate extremes and adaptive management on the Colorado River: lessons from the 1997–1998 ENSO event. *Journal of Environmental Management, 63*(3), 307-324.

Ranney, M. A., & Clark, D. (2016). Climate Change Conceptual Change: Scientific Information Can Transform Attitudes. *Topics in Cognitive Science, 8*(1), 49-75. doi:10.1111/tops.12187

Ranney, M. A., Clark, D., Reinholz, D., & Cohen, S. (2012). *Changing global warming beliefs with scientific information: knowledge, attitudes, and RTMD (Reinforced Theistic Manifest Destiny theory)*. Paper presented at the 34th Annual Meeting of the Cognitive Science Society, Austin, TX.

Ratner, R. K., & Riis, J. (2014). Communicating science-based recommendations with memorable and actionable guidelines. *Proceedings of the National Academy of Sciences, 111*(Supplement 4), 13634-13641. doi:10.1073/pnas.1320649111

Read, D., Bostrom, A., Morgan, M. G., Fischhoff, B., & Smuts, T. (1994). What Do People Know About Global Climate Change? 2. Survey Studies of Educated Laypeople. *Risk Analysis, 14*(6), 971-982. doi:10.1111/j.1539-6924.1994.tb00066.x

Reddy, M. J. (1979). The conduit metaphor: A case of frame conflict in our language about language. In A. Ortony (Ed.), *Metaphor and thought* (Vol. 2, pp. 164-201).

Reynolds, T. W., Bostrom, A., Read, D., & Morgan, M. G. (2010). Now What Do People Know About Global Climate Change? Survey Studies of Educated Laypeople. *Risk Analysis, 30*(10), 1520-1538. doi:10.1111/j.1539-6924.2010.01448.x

Rice, D. C., Ryan, J. M., & Samson, S. M. (1998). Using concept maps to assess student learning in the science classroom: Must different methods compete? *Journal of Research in Science Teaching, 35*(10), 1103-1127. doi:10.1002/(SICI)1098-2736(199812)35:10<1103::AID-TEA4>3.0.CO;2-P

Roehm, Michelle L., & Sternthal, B. (2001). The Moderating Effect of Knowledge and Resources on the Persuasive Impact of Analogies. *Journal of Consumer Research, 28*(2), 257-272. doi:10.1086/322901

Rowan, K. E. (1988). A Contemporary Theory of Explanatory Writing. *Written Communication, 5*(1), 23-56. doi:10.1177/0741088388005001002

Rowan, K. E. (1991). Goals, obstacles, and strategies in risk communication: A problem-solving approach to improving communication about risks. *Journal of Applied Communication Research, 19*(4), 300-329. doi:10.1080/00909889109365311

Rowan, K. E. (2003). Informing and explaining skills: Theory and research on informative communication. In J. O. Greene & B. R. Burleson (Eds.), *Handbook of communication and social interaction skills* (pp. 403-438). Mahwah, NJ, US: Lawrence Erlbaum Associates Publishers.

Rowan, K. E. (in press). Types of explanation. In R. L. Parrott (Ed.), *Oxford Encyclopedia of Health Message Design*. London: Oxford.
Russill, C. (2011). Temporal Metaphor in Abrupt Climate Change Communication: An Initial Effort at Clarification. In W. L. Filho (Ed.), *The Economic, Social and Political Elements of Climate Change* (pp. 113-132): Springer Berlin Heidelberg.
Schön, D. A. (1993). Generative metaphor: A perspective on problem-setting in social policy. In A. Ortony (Ed.), *Metaphor and thought*. London/New York: Cambridge University Press.
Seacrest, S., Kuzelka, R., & Leonard, R. (2000). GLOBAL CLIMATE CHANGE AND PUBLIC PERCEPTION: THE CHALLENGE OF TRANSLATION1. *JAWRA Journal of the American Water Resources Association, 36*(2), 253-263. doi:10.1111/j.1752-1688.2000.tb04265.x
Searles, K., & Ryan, J. B. (May 4, 2015). Researchers are rushing to Amazon's Mechanical Turk. Should they? *The Washington Post*. Retrieved from http://www.washingtonpost.com/blogs/monkey-cage/wp/2015/05/04/researchers-are-rushing-to-amazons-mechanical-turk-should-they/
Selin, C. (2006). Trust and the illusive force of scenarios. *Futures, 38*(1), 1-14. doi:http://dx.doi.org/10.1016/j.futures.2005.04.001
Semino, E. (2008). *Metaphor in Discourse*. Cambridge: Cambridge University Press.
Shapiro, M. A. (1986). *Analogies, visualization, and mental processing of science stories* (Vol. 9). Newbury Park, CA: Sage.
Shihusa, H., & Keraro, F. N. (2009). Using Advance Organizers to Enhance Students' Motivation in Learning Biology. *Eurasia Journal of Mathematics, Science & Technology Education, 5*(4), 413-420.
Simons, P. R. (1984). Instructing with analogies. *Journal of Educational Psychology, 76*(3), 513-527. doi:10.1037/0022-0663.76.3.513
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.
Slovic, P. E. (2000). *The perception of risk*: Earthscan publications.
Snowdon, C., Garcia, J., & Elbourne, D. (1997). Making sense of randomization; responses of parents of critically ill babies to random allocation of treatment in a clinical trial. *Social science & medicine, 45*(9), 1337-1355. doi:http://dx.doi.org/10.1016/S0277-9536(97)00063-4
Somerville, R. C. J., & Hassol, S. J. (2011). The science of climate change. *Phys. Today, 64*(10).
Sopory, P., & Dillard, J. P. (2002). The Persuasive Effects of Metaphor: A Meta-Analysis. *Human Communication Research, 28*(3), 382-419. doi:10.1111/j.1468-2958.2002.tb00813.x
Stewart, J., Van Kirk, J., & Rowell, R. (1979). Concept maps: A tool for use in biology teaching. *The American Biology Teacher, 41*(3), 171-175.
Thibodeau, P. H., & Boroditsky, L. (2013). Natural Language Metaphors Covertly Influence Reasoning. *PLoS ONE, 8*(1), e52961. doi:10.1371/journal.pone.0052961

Thibodeau, P. H., & Durgin, F. H. (2008). Productive figurative communication: Conventional metaphors facilitate the comprehension of related novel metaphors. *Journal of Memory and Language, 58*(2), 521-540. doi:10.1016/j.jml.2007.05.001

Turner, M., & Lakoff, G. (1989). *More than cool reason: A field guide to poetic metaphor*: Chicago: University of Chicago Press.

Väliverronen, E., & Hellsten, I. (2002). From "Burning Library" to "Green Medicine" The Role of Metaphors in Communicating Biodiversity. *Science Communication, 24*(2), 229-245. doi:10.1177/107554702237848

van der Linden, S., Leiserowitz, A., Feinberg, G., & Maibach, E. (2014). How to communicate the scientific consensus on climate change: plain facts, pie charts or metaphors? *Climatic Change, 126*(1-2), 255-262. doi:10.1007/s10584-014-1190-4

van Dijk, T. A. (1987). Episodic models in discourse processing. In R. Horowitz & S. J. Samuels (Eds.), *Comprehending oral and written language* (pp. 161-196). New York: Academic Press.

Volmert, A. (2014). *Getting to the Heart of the Matter: Using Metaphorical and Causal Explanation to Increase Public Understanding of Climate and Ocean Change*. Retrieved from Washington, D.C.:

Weber, E. U. (1997). The utility of measuring and modeling perceived risk. In A. A. J. Marley (Ed.), *Choice, Decision, and Measurement: Essays in Honor of R. Duncan Luce* (pp. 45-57). Mahwah: Lawrence Erlbaum Associates.

Weber, E. U., & Stern, P. C. (2011). Public understanding of climate change in the United States. *American Psychologist, 66*(4).

Whitney, P., Budd, D., & Mio, J. S. (1996). Individual differences in metaphoric facilitation of comprehension. In J. S. Mio & A. N. Katz (Eds.), *Metaphor: Implications and applications* (pp. 203–214). Mahwah, NJ: Erlbaum.

Willerman, M., & Mac Harg, R. A. (1991). The concept map as an advance organizer. *Journal of Research in Science Teaching, 28*(8), 705-711. doi:10.1002/tea.3660280807

Wilson, K. M. (1995). Mass media as sources of global warming knowledge. *Mass Comm Review, 22*, 75-89.

Wright, G., & Ayton, P. (1987). Eliciting and modelling expert knowledge. *Decision Support Systems, 3*(1), 13-26. doi:http://dx.doi.org/10.1016/0167-9236(87)90032-7

Zaltman, G. (2003). *How customers think: essential insights into the mind of the market*. Boston, MA: Harvard Business School Press.

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