THE INFLUENCE OF WEATHER ON PERCEPTIONS OF PERSONAL EXPERIENCE WITH CLIMATE CHANGE AND EXTREME WEATHER IN NEW YORK STATE

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ABSTRACT

The general public's understanding of climate change may be shaped by weather through a mechanism called experiential processing, in which an individual's personal experience influences their perceptions of a topic. Experiential processing is strongly influenced by recent and vivid situations, even for climate change, which is a long-term, global trend. This thesis examines how different types of recent weather conditions and extreme weather events affect New York State adults' perceptions of climate change and extreme weather in 2014. Findings suggest that warmer temperatures and the absence of winter weather conditions increase individuals' perceptions that they have experienced climate change or extreme weather. However, results also indicate that belief in the reality of climate change more strongly influences perceptions of personal experience than do actual weather conditions. This supports previous research that experiential processing is limited by pre-existing perceptions shaped by values or other sources of information.

BIOGRAPHICAL SKETCH

Jennifer R. Fownes was born on the island of Oahu. She spent her childhood in Hawaii, lodging the beaches and rainforests firmly in her heart and the tropical weather in her blood. After age eight, Jennifer's family relocated to small hilltown outside Amherst, Massachusetts, surrounding her with an entirely different forest. As a student at Dartmouth College, Jennifer explored many areas of study and locations, traveling to Argentina to learn about Hispanic culture, singing in a classical choir on campus, traipsing through the jungles of Costa Rica and scuba diving in coral reefs off Little Cayman Island for a tropical field ecology program, and dancing the night away at a swing dance class. While an undergraduate, she dabbled in many areas of biology, from studying the impacts of road noise on cricket calls in New Hampshire to investigating how iron-oxidizing bacteria colonize steel surfaces.

After graduating from Dartmouth in 2011, Jennifer moved to Washington, DC, to try her hand at environmental consulting. At ICF International, as part of the Environmental and Social Sustainability team, Jennifer worked on human health and ecological risk assessments, learned Excel tricks, and evaluated chemical safety labeling standards from a variety of countries.

Jennifer came to Ithaca with Nozomi Hitomi (another Dartmouth '11) as he started his PhD in Mechanical and Aerospace Engineering at Cornell, with the goal of pursuing her Masters there. To dive back into research, she worked as a lab technician for Dr. Esther Angert's lab of the Microbiology Department and Dr. Clifford Kraft of the Department of Natural Resources (DNR), studying bacteria that produce a Vitamin B1-destroying enzyme. Jennifer joined the Human Dimensions Research Unit of DNR for her Masters to learn they ways in which social and psychological factors shape how individuals and policymakers understand environmental issues.

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[1] Rosenzweig, C., Solecki, W., DeGaetano, A., O'Grady, M., Hassol, S., & Grabhorn, P. (2011). *Responding to Climate Change in New York State: the ClimAID Integrated Assessment for Effective Climate Change Adaptation in New York State*. Albany, NY. Retrieved from www.nyserda.ny.gov

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TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

C	Celsius
ESP	Empire State Poll
F	Fahrenheit
IPCC	Intergovernmental Panel on Climate Change
NOAA	National Oceanic and Atmospheric Administration
NYS	New York State
UK	United Kingdom
US	United States

PREFACE

I approached the Secretary of the National Environmental Commission for the Kingdom of Bhutan (and Cornell University MS ’95) following his presentation as a side event panelist during the United National Framework Convention on Climate Change 22nd Convention of the Parties in Marrakech, Morocco, in November, 2016. As a graduate student constantly reading and thinking about climate change – what we can measure and estimate scientifically, how people live through its impacts or think about the future, and the interaction between individual and collective actions – I was interested in hearing the perspective of a government official who had just presented on the theme of “Adaptation to Climate Change.” Using the Cornell connection, I introduced myself and, of course, my research topic: how personal experience with weather influences perceptions of climate change. I was surprised to learn that the Secretary, Mr. Chencho Norbu, had one of these experiences himself. He told me that the moment he was fully convinced that we needed to take action on climate change came upon seeing firsthand the receding glaciers in Bhutan.

This thesis seeks to understand a little more about the experiences that can shape these moments, from small everyday fluctuations in weather to severe and memorable events.

INTRODUCTION

"Climate change, once considered an issue for a distant future, has moved firmly into the present." – Third National Climate Assessment (Melillo, Richmond, & Yohe, 2014)

Across the United States (US), climate change is already altering weather and impacting lives and livelihoods. These changes, and the scientific confidence in their reality and anthropogenic cause, are documented in the Third National Climate Assessment (Melillo et al., 2014). Climate change is warming temperatures and shifting patterns of rainfall and snowfall, often leading to shorter, warmer winters and hotter, drier summers. As average weather changes, so does the range of possible weather events; previously rare events are becoming more common, including heat waves, heavy downpours, flooding, wildfires, droughts, and severe storms. Extreme weather events and more subtle changes in weather conditions both pose challenges to agriculture, infrastructure, a variety of sectors, natural resources, and human health, and affect societies through interactions with pre-existing vulnerabilities, including susceptibility to impacts (e.g., cities local in a flood plain or on the coastline) and capacity to respond or adapt (IPCC, 2014).

Perceptions of Climate Change and Weather

Despite the documentation of widespread climate impacts, only 33% of Americans say that they have experienced the effects of climate change (Leiserowitz, Maibach, Roser-Renouf, Rosenthal, & Cutler, 2017). This may be partly due to the high variability in climate impacts across space and time. Average land surface temperatures (from 1901-2012) have increased by up to 1.5 °C across much of the United States (US), but in the parts of the southern US there has been no change or even a 0.2 °C decrease (IPCC, 2014). Temperature and precipitation vary greatly across seasons, years, and even decades, meaning that climate change must be detected over periods of 30 years or more (IPCC, 2014). Although there is currently high confidence among scientists in attributing climate change to human causes (IPCC, 2014), natural fluctuations in weather and the multiple sources of (invisible) greenhouse gases challenge the detection of anthropogenic influences through individuals' personal experience (Weber & Stern, 2011).

There is a tendency for the general public to conflate climate change and weather (Reynolds, Bostrom, Read, & Morgan, 2010). This may explain why individuals who have personally experienced the impacts of extreme weather are more likely to think that such events are becoming worse. For example, in a 2013 survey in the UK, respondents who had experienced flooding in their area believed that water-related weather events (including flooding, heavy rainfall, and coastal erosion) were becoming more frequent, while respondents who had experienced discomfort, illness, or transportation disruption during heat waves believed that high temperature events (heat waves, hot summers, and dry periods without rain) were becoming more frequent (Taylor, De Bruin, & Dessai, 2014). Similarly, temperatures on a single day can significantly influence perceptions of temperature trends over one year or multiple years (e.g., Joireman, Barnes Truelove, & Duell, 2010; Zaval, Keenan, Johnson, & Weber, 2014).

Such perceptions can shape climate change beliefs, concerns, and actions. For example, a longitudinal study of US residents in 2008 and 2011 found that perceptions of having personally experienced the effects of global warning were significantly related to increased belief in climate change at a later time, even when controlling for belief at the beginning of the study (Myers, Maibach, Roser-Renouf, Akerlof, & Leiserowitz, 2013). Similarly, a survey of UK and

Australian residents in 2010 found that respondents who reported that they had experienced the impacts of climate change (in the form of seasonal changes, extreme weather, environmental changes, water scarcity, increased rainfall, and sea level rise) had greater belief in climate change, perceptions of climate risk, and engagement in mitigation behaviors (Reser et al., 2012).

This thesis draws on theories of psychological processing, the way in which people understand new information (Epstein, 1994; Loewenstein, Weber, Hsee, & Welch, 2001; Marx et al., 2007; Sloman, 1996; Weber, 2010), to understand the relationship between personal experience with weather and perceptions of climate change. Psychological processing of personal experience is examined through the lens of construal level theory or psychological distance (Brügger, Morton, & Dessai, 2016; Liberman & Trope, 2008; Trope & Liberman, 2010) in Chapter 1, and risk perception theories including prospect theory and the risk-as-feelings hypothesis (Hertwig, Barron, Weber, & Erev, 2012; Kahneman & Tversky, 1979; Keller, Siegrist, & Gutscher, 2006; Loewenstein et al., 2001; Marx et al., 2007; Yechiam, Barron, & Erev, 2005) in Chapter 2.

Theoretical Background

Personal experience with extreme weather events "made climate change real" for respondents in a 2010 survey of the UK and Australia (Reser, Bradley, & Ellul, 2014, p. 526). In the psychological literature, this phenomenon is known as *experiential processing*, in which present experiences are unconsciously understood in comparison to past experiences in order to update understandings about a topic (Epstein, 1994; Loewenstein et al., 2001; Weber, 2010). For example, in a 2011 survey in Michigan, respondents who reported having experienced the effects of climate change were more likely to think that climate change would have local impacts in the future (Akerlof, Maibach, Fitzgerald, Cedeno, & Neuman, 2013).

Experiential processing can be contrasted with *analytical processing*, a way of understanding new information that relies on logical thought (Epstein, 1994; Loewenstein et al., 2001; Sloman, 1996). While experiential processing is vivid and emotional (Epstein, 1994; Loewenstein et al., 2001; Weber, 2010), analytical processing is rational, abstract, and symbolic (Epstein, 1994; Loewenstein et al., 2001; Sloman, 1996). Scientific descriptions of climate change – statistics, projections of possible future events, long-term global assessments – are understood through analytical processing. However, experiential processing is influenced by local climate and, in the short term, weather conditions.

While people employ both types of processing, experiential processing can often overwhelm analytical (Marx et al., 2007; Sloman, 1996). For example, surveys in Michigan and Pennsylvania in 2007 found that more respondents based their belief in climate change on personal experience with local temperatures than based it on analytical information (computer models of climate change or the documentary "An Inconvenient Truth") (Borick & Rabe, 2010). The literature on risk perceptions credits the persuasiveness of experiential processing to the emotional aspect of personal experience, the *risk-as-feelings* hypothesis (Loewenstein et al., 2001). A series of studies performed in Switzerland in 2004 found that respondents believed that flooding risks were perceived as higher by respondents with more emotional information, either as past personal experience with floods or images of flooding, instead of just a description of flood events (Keller et al., 2006). However, in the case of climate change, spatial and temporal variability of extreme weather events means that such events will be rare but can be very salient and influential when they do happen. As a result, experiential processing is likely to create biased perceptions of weather and climate.

The concept of *psychological distance* explains how mental representations of information are weighted, based on the characteristics of that information (Liberman & Trope, 2008). There are four characteristics, based on types of distance: spatial distance, temporal distance, social distance, and certainty or hypothetical distance (Liberman & Trope, 2008; Trope & Liberman, 2010). Cognitively, it is easiest to represent topics as either "close" on all types of distance, or "far" on all types of distance (Brügger et al., 2016). Personal experiences with weather are "close", as they occur to oneself at the present location and time (Trope & Liberman, 2010), while analytical information about far away and long-term or future climate impacts is "far" (Brügger et al., 2016).

As a result, perceptions of personal experience with climate change will likely be weighted towards the "closest" or more recent experiences, such as weather on the current day or recent extreme events (or lack thereof). The concept of psychological distance appears in the risk literature as *prospect theory*, which focuses on timing and certainty: uncertain or future events are discounted in comparison to certain past or future events (Kahneman & Tversky, 1979). Perceptions of extreme weather events will be even more biased than perceptions of average weather states: extreme weather events are rare and therefore are disregarded during long periods without them, but they are very vivid and can cause emotional stress, making them especially memorable and more highly weighted right after they happen (Hertwig et al., 2012; Marx et al., 2007; Weber & Stern, 2011).

However, symbolic (analytical) understandings of climate change are still very important. Despite scientific consensus, there is a divide in public opinion on whether climate change is anthropogenic and when its effects will begin (Leiserowitz et al., 2017), and as a result knowledge about these topics is often referred to as *beliefs* instead of *facts*. Climate change beliefs are shaped by values and ideology, and therefore polarized among different groups, such as those defined by political party (Dunlap, McCright, & Yarosh, 2016). According to the *cultural cognition of risk thesis*, beliefs that are strongly tied to group identities will be hard to change, because individuals have motivation to maintain their group identity (Kahan et al., 2012). As a result, these individuals would be less likely to update their perceptions of weather and climate change based on actual conditions or events, and more like to interpret their experiences to match their preconceived expectations, a process known as *motivated reasoning* (Chen, Duckworth, & Chaiken, 1999; Kahan et al., 2012; Myers et al., 2013). For instance, in early 2015 Senator Inhofe brought a snowball into a Senate hearing, using it to emphasize his interpretation of a recent cold spell as an indication that climate change was not happening (Cama, 2015), despite scientific evidence to the contrary.

Perceptions of Personal Experience with Weather

This thesis is informed by previous studies that have evaluated the role of experiential processing in shaping perceptions of extreme weather and climate change by testing whether perceptions of weather or climate change relate to actual weather conditions. This thesis consists of two chapters that consider experiential processing of 1) weather conditions weather and 2) extreme weather events, and therefore the literature will be divided into two sections. The focus of the current study is the general public in developed countries, and therefore the literature review will be limited to research on this population.

Weather Conditions

Experiential processing in this context refers to the way in which individuals' perceptions of temperature and precipitation over a specific time period are based on information provided by actual conditions. For example, temperatures on the current day influence perceptions of current temperatures (Li, Johnson, & Zaval, 2011; Zaval et al., 2014). However, perceptions of temperatures for a year or more do not accurately match actual conditions (Goebbert, Jenkins-Smith, Klockow, Nowlin, & Silva, 2012; Howe & Leiserowitz, 2013; Howe, Markowitz, Lee, Ko, & Leiserowitz, 2013; Shao & Goidel, 2016), suggesting that individuals' perceptions of long-term weather conditions may be influenced by other sources of information or not remembered. There is evidence that individuals' perceptions of multi-year temperature patterns are related to temperatures from a single day (Joireman et al., 2010; Zaval et al., 2014), suggesting that recent personal experiences can also influence perceptions of overall weather.

Previous studies on perceptions of precipitation have been limited by the available spatial and temporal resolution of precipitation data (e.g., Hamilton & Stampone, 2013). One study was identified that provides mixed evidence for the ability of individuals to accurately perceive seasonal precipitation trends over the preceding year (Howe & Leiserowitz, 2013). As a result, the accuracy of the public's perceptions of local precipitation is not currently well understood.

Two studies evaluated the influence of actual seasonal temperature and precipitation trends (over three to thirty-eight years) on perceptions of overall changes in either weather or climate change (Hamilton & Keim, 2009; Shao, 2016). These studies provide mixed evidence for experiential processing about general and weather climate trends. Similarly to the studies on perceptions of long-term temperature conditions, this suggests that individuals may not be able to remember past weather conditions for long or associate them with climate change.

Extreme Weather Events

Studies on experiential processing of extreme weather events examined multiple types of weather events. No studies were identified that investigated the relationship between extreme temperatures (such as heat waves) and perceptions of temperature or heat. Multiple studies found that actual and perceived experiences with hurricanes were significantly related (Howe, Boudet, Leiserowitz, & Maibach, 2014; Shao & Goidel, 2016), suggesting that large and salient extreme events are influential to perceptions. There is mixed evidence as to whether perceptions of personal experience with flooding are significantly related to actual events (Goebbert et al., 2012; Shao, 2016), likely related to multiple interacting factors that lead to flooding (Whitmarsh, 2008). Most studies of drought perceptions have found that they are significantly related to actual drought levels (Akerlof et al., 2013; Goebbert et al., 2012; Howe et al., 2014), although one did not (Shao & Goidel, 2016).

Studies on perceptions of experience overall extreme weather events suggest that perceptions are more accurate for recent events compared to older ones (Akerlof et al., 2013; Shao, 2016; Shao & Goidel, 2016). One additional study found that perceptions of the local effects of extreme weather were related to damages (impacts) from extreme weather instead of the incidence of events themselves (Cutler, 2015).

Thesis Objectives

The purpose of this thesis is to examine the role of experiential processing in forming perceptions of climate change in New York State (NYS). NYS was selected because it has diverse climate regions, and therefore a variety of climate impacts: increased frequency of intense heat events, reduced extreme cold events, heavy rainfall and sea level rise leading to flooding, and severe storms (Rosenzweig et al., 2011). These impacts generally match those found in previous research to be associated with climate change by the general public: warming temperatures, river and coastal flooding (or sea level rise), extreme weather, and melting glaciers (not occurring in NYS), drought, and forest fire (Akerlof et al., 2013; Borick & Rabe, 2010;

Leiserowitz, 2006; Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Howe, 2012b; Whitmarsh, 2008).

The dependent variable of interest across the two main thesis chapters is perceptions of personal experience with the effects of extreme weather or climate change, measured in a survey of NYS adults in early 2014. Recognizing that pre-existing beliefs may limit the extent of experiential processing, belief in climate change (measured through the same survey) is included as a control in analyses.

Chapter 1 examines the relationship between respondents' perceptions of personal experience with climate change or extreme weather and different types of recent weather conditions (temperature and precipitation). The focus on recent weather is based on the theory of psychological distance and previous findings that recent weather is highly weighted in perceptions. This chapter tests whether salient "recent" experiences occur on the current day day or are a culmination of a slightly longer period (the preceding week). This chapter also tests if respondents' self-reported experience with weather and climate is based on absolute weather conditions (the raw temperature or amount of precipitation) or relative conditions (whether it is warmer/colder than usual or wetter/dryer than usual).

Chapter 2 examines the relationship between perceptions of personal experience and different types of extreme weather. The measurement of extreme weather events is limited to the past three years prior to the survey, as prospect theory suggests that more certain extreme events (those that have happened more recently instead of possibly happening in the future) will be the most salient, while still capturing multiple years to increase the number of total events that occurred. Two types of extreme weather events were selected because the public may associate them with climate change and they occurred in many NYS counties during the study period: 1) winter weather and extreme cold events, and 2) flood events. Extreme weather events were measured in two ways to assess whether experiential processing of extreme weather events is more influenced 1) by an event happening (measured as the number of extreme events) or 2) by its magnitude (property damage caused).

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CHAPTER 1

THE INFLUENCE OF RECENT WEATHER ON PERCEPTIONS OF PERSONAL EXPERIENCE WITH CLIMATE CHANGE AND EXTREME WEATHER

Abstract

The general public's perceptions of climate change may be shaped by their personal experience with its impacts. Experiential processing is an automatic and associative process through which individuals understand new information based on their current situation and associate it with a topic. Although climate change is a long-term, global trend, individuals personally experience it as local weather from moment to moment. As a result, the public's perceptions of their overall personal experiences with climate change may be strongly influenced by very recent weather conditions. This study examines how New York State adults' perceptions of climate change and extreme weather in early 2014 are related to different types of recent weather (temperature and precipitation), measured either as deviations from normal conditions or as raw conditions. Findings suggest that warmer temperatures for one day or one week increase individuals' perceptions that they have experienced climate change or extreme weather. This study also accounts for respondents' climate change belief, which influences them to interpret any weather conditions as evidence for their existing perceptions of whether climate change is happening.

Introduction

All regions of the US have already felt the impacts of climate change, including warmer temperatures, changes in precipitation patterns, and an increase in extreme weather events (Melillo et al., 2014). However, only one third of American adults currently report having ever personally experienced the effects of climate change (Leiserowitz et al., 2017). Almost twice as many (60%) think that global warming is affecting weather in the US at least a little bit, reflecting a tendency for climate change to be considered a distant threat – more likely to harm *other* places or people, or to happen in the future (Leiserowitz et al., 2017).

Some authors have suggested that visible local or personal climate change impacts can make the general public more concerned and more likely to respond to the issue (e.g., Lorenzoni & Pidgeon, 2006; Spence, Poortinga, & Pidgeon, 2012; Weber, 2006). There is evidence that perceptions of personal experience with climate change can influence climate change beliefs, concerns, risk perceptions, and mitigation behaviors (Akerlof et al., 2013; Myers et al., 2013; Shao, 2016). For example, self-reported experience with climate change was significantly related to stronger beliefs in climate change at a later time (Myers et al., 2013). However, recent work reveals that the influence of perceived personal experience on responding to climate change is more complicated. For instance, the perception of personal threats from climate change can actually decrease motivation to act by triggering fear-avoidance mechanisms, feelings of low self-efficacy, or guilt and forced responsibility (Brügger, Dessai, Devine-Wright, Morton, & Pidgeon, 2015).

Perceptions of climate change and associated impacts may be shaped through actual personal experience with weather and climate. The psychological literature describes two main ways in which people process new information: analytical (logical, conscious reasoning) and experiential (unconscious associations between current and previous situations) (Epstein, 1994; Loewenstein et al., 2001; Sloman, 1996). Experiential processing is vivid and emotional, and there is evidence that experiential information often outweighs analytical information, especially when individuals are trying to understand complex topics such as risk or climate change (Epstein, 1994; Loewenstein et al., 2001; Marx et al., 2007; Sloman, 1996; Weber, 2010).

An individual experiences climate change at a particular place and moment, while changes to the Earth's climate system and the resulting impacts of shifting weather patterns and extreme events vary across space and time. As a result, it is important to know which aspects of weather or climate individuals rely on when experientially processing information about climate change. The concept of psychological distance refers to how topics tend to be represented cognitively as "close" or "distant" in four different aspects: space, time, social similarity, and certainty (Liberman & Trope, 2008; Trope & Liberman, 2010). Individuals' perceptions of personal experience with any topic, which is psychologically close, will tend to rely mostly on other close experiences. As a result, even though climate change is a long-term, global phenomenon, individuals' perceptions of their personal experience with climate impacts will be weighted towards their recent local experiences.

Additionally, the general public tends to confuse weather, a local climate state at a particular time, with climate, a long-term global average (Reynolds et al., 2010). Therefore there is the potential for people to confuse personal experience with weather and personal experience with climate change. This is supported by evidence that climate change beliefs, risk perceptions, and responses are related to recent weather, such as temperatures over the preceding day or week (e.g, Egan & Mullin, 2012; Hamilton & Stampone, 2013; Li, Johnson, & Zaval, 2011). Additionally, previous studies suggest that perceptions of personal experience with climate change effects are related to actual local long-term temperature trends (Hamilton & Keim, 2009), and that perceptions of long-term temperature trends can be influenced the short-term temperatures, such as actual temperature on a single day (Joireman et al., 2010; Zaval et al., 2014). The current study examines how different types of recent weather shape perceptions of personal experience with climate change.

In addition, climate change is an increasingly politically polarized issue (Dunlap et al., 2016) and therefore there is the potential for social-psychological factors to influence climate change views. Individuals tend to maintain beliefs consistent with those of their group members (Kahan, 2013), such as Democrats believing that climate change is happening and Republicans denying it (Dunlap et al., 2016). In order to preserve these beliefs in the face of new evidence – such as personal experiences with climate change impacts – individuals interpret new information with the goal of arriving at the same conclusions they started with, a process called motivated reasoning (Kunda, 1990). There is evidence that pre-existing beliefs about climate change influence how individuals perceive their experiences with climate change or weather (Myers et al., 2013; Reser et al., 2012; Shao, 2016). To account for motivated reasoning, the current study also evaluates the impact of climate change belief on perceptions of personal experience, and compares this to the influence of recent weather.

Literature Review

This section will describe how individuals understand new information about climate change, using the theory of psychological processing, which defines two mechanisms by which people comprehend new information: analytical and experiential. Experiential processing builds perceptions of a topic through personal experiences. Personal experience occurs to oneself, at the present time, in a current location, and is certain; therefore, it can be described as “close” using the theory of psychological distance, which divides the mental representation of objects into close and distant categories. As a result, weather would be seen as psychologically close, while climate change (a long-term, global, phenomenon happening to many people and often portrayed as uncertain), would be psychologically distant. However, the general public often confuses weather and climate change (Reynolds et al., 2010) and therefore may interpret short-term weather conditions as indicative of climate change.

As a result, there is the potential for weather to influence the public's perceptions of their personal experience with both weather and climate change. The second section below will review previous literature on the effect of different types of weather on perceptions of personal experience with climate change and weather.

Psychological Processing

As previously described, individuals understand new information through analytical and experiential psychological processing (Epstein, 1994; Loewenstein et al., 2001; Sloman, 1996). *Analytical processing*, alternatively referred to as *rational thinking* or *rule-based thinking* or *cognitive evaluation*, is characterized by logical, conscious reasoning and is capable of handling abstract and symbolic concepts (Epstein, 1994; Loewenstein et al., 2001; Sloman, 1996). On the other hand, *experiential processing* is an unconscious and associative system in which the present situation is understood through a comparison to previous experiences through heuristics, or cognitive shortcuts (Epstein, 1994; Sloman, 1996). Experiential processing is more spontaneous, vivid, and affective (emotional) than analytical processing (Epstein, 1994; Loewenstein et al., 2001; Weber, 2010). People rely on a combination of both mechanisms when processing an experience, although experiential is often more influential unless analytical information is presented in a very concrete way (Marx et al., 2007; Sloman, 1996).

Climate change is a complex phenomenon, with effects that differ across spatial and temporal scales. Over the past 100 years, average global land and ocean surface temperatures and sea level have increased, altering trends and variability in temperature and precipitation (IPCC, 2014). However, these long-term trends differ geographically. For example, from 1901-2012 average land surface temperatures have increased by up to 1.5 °C across most of the United States (US), but in parts of the southern US there has been no change or even a decrease by 0.2 °C over this same time period (IPCC, 2014). Additionally, previously rare events are becoming more common, meaning that the range of possible temperature or precipitation is getting larger. For example, in New York State the frequency of heavy precipitation events has increased in recent decades, even though the average precipitation levels have stayed the same since 1900 (Rosenzweig et al., 2011).

Climate change is an abstract concept, described by statistical analysis of meteorological conditions that vary greatly over space and time, projections of possible future impacts, and caused by invisible greenhouse gases (Weber & Stern, 2011). This would suggest that analytical processing could be a way in which people learn about climate change, and that general levels of belief in climate change would follow analytical, or scientific, knowledge about climate change. However, there is a widening gap between the general public and scientific consensus over the reality and causes of climate change: over 90% of climate scientists think that anthropogenic climate change is happening (Cook et al., 2016), while 70% of the American public believe that climate change is happening and only 55% believe that it is mostly caused by humans (Leiserowitz et al., 2017). Additionally, a 2010 US study found that increasing math and science abilities did not increase respondents' perceptions of climate change risk (Kahan et al., 2012). A 2013 study found that, instead, climate-specific information (on the causes and impacts of climate change and possible mitigating actions) increased respondents' concerns about climate change as well as their support for mitigation, including individual behaviors and policy measures related to reducing energy consumption and greenhouse gas emissions (Shi, Visschers, & Siegrist, 2015). This suggests that the public better understands specific messages (e.g., climate change is already causing an increase in heat waves in my local area) compared to more general information (e.g., a map of temperature trends across the globe for the past 100 years or descriptions of the global climate system).

Experiential processing may have the greater influence on the general public's views about complex and uncertain topics such as climate change. Studies on decision-making show that under uncertainty, individuals rely more on experiential rather than analytical information (Loewenstein et al., 2001; Marx et al., 2007). For example, in a study of monetary gambling behavior, individuals made better decisions in risky scenarios when they were allowed to test them first-hand instead of being told probabilities (Weber, Shafir, & Blais, 2004). This preference for experiential processing increases with the complexity of the activity (Lejarraga, 2010).

Experiential processing of climate change occurs when an individual has a personal experience with the climate. However, personal experience occurs at a specific place and time and therefore each experience is not always representative of the long-term global climate state and changes to it. Climate is average weather, generally quantified over a period of 30 years or more (IPCC, 2014). However, even if individuals in many locations thought about and compared 30 years of their personal experience, this would not match objective measures of climate change, because the mechanisms of experiential processing introduce bias.

The psychological processing of personal experience can be examined through construal level theory, which describes how mental representation of objects (or construals) are related to how *psychologically distant* they are (Liberman & Trope, 2008). As mentioned previously, psychological distance is comprised of four different aspects: spatial distance, temporal distance, social distance, and certainty or hypothetical distance (Liberman & Trope, 2008; Trope & Liberman, 2010). Personal experience is psychologically close, as it refers to a subjective experience that is specific to an individual, occurring at a specific location and time (Trope & Liberman, 2010). On the other hand, past experiences, estimates of future change, and global or far-off climate will all be psychologically distant.

During decision-making, psychologically close information (e.g., perceptions based on personal experience) will be linked to other psychologically close mental constructs, including emotions (e.g., fear of perceived risks) (Brügger et al., 2016). On the other hand, analytical information will be associated with abstract – psychologically distant – concepts such as values and ideology (Brügger et al., 2016; Clarke et al., 2016). Beliefs about climate change are currently very polarized among different groups, especially those defined by political party and ideology (Dunlap et al., 2016). The *cultural cognition thesis* suggests that individuals tend to adhere to the values of the groups with which they identify (Kahan et al., 2012), and therefore analytical information is unlikely to change pre-existing beliefs.

There can also be an interaction between the perception of new personal experiences and existing (abstract) ideas about climate change. *Motivated reasoning* refers to the process by which individuals interpret experiences based on their pre-existing beliefs (Myers et al., 2013). A study of US adults found evidence for both experiential processing and motivated reasoning based on within-subjects longitudinal data (in 2008 and 2011): respondents' perceived personal experience with climate change influenced later belief in climate change, while earlier belief in climate change also influenced later perceptions of personal experience with climate change (Myers et al., 2013). Furthermore, it seems that the strength of motivated reasoning is related to psychological distance: distant topics favors abstract thinking, and thus existing values drive motivated reasoning about any new information (Clarke et al., 2016). As a result, if climate change is perceived as a distant threat, then political polarization of beliefs, risk perceptions, and responses will be the most divided; alternatively, if climate change is perceived as close or having personal impacts, individuals' beliefs, concerns, and response will be related to the local context (Brügger et al., 2015).

Perceptions of Personal Experience with Climate Change

This section will review previous research on the relationship between actual weather and perceptions of personal experience with climate change or weather. This review is limited to studies of the general public in developed countries to match the context of the current study. Few studies were identified that examined the relationship between perceptions explicitly about climate change and actual weather. Instead, most studies measured individuals' perceptions of changes in weather that the public may associate with climate change: temperature and precipitation. The literature reviewed focuses on weather conditions and trends, and does not include studies on perceptions of personal experience with extreme weather, which are measured as discrete events. This review is divided into three sections, based on the types of weather identified in previous studies, and within each section, studies will be discussed in order of increasing time periods assessed.

Perceptions of Temperature

Local impacts of climate change for many parts of the world – and most of the US – include increased average temperatures as well as an increased frequency of extremely hot temperatures and a decrease in extremely cold temperatures (IPCC, 2014). As a result, individuals may tend to experience warmer days on average and more frequent unusually hot days, in which case local impacts will mirror global trends. Additionally, rising temperature is the most salient impact of climate change to the general public: in a 2002-2003 US survey, participants providing word associations for "global warming" most frequently mentioned the topic of temperature changes and warming, including the resulting melting glaciers and polar ice (Leiserowitz, 2006). Many studies have related individuals' experience with temperature to actual temperatures (described below). Temperature data is available at a spatially local and temporally frequent level, and therefore can be linked to individual subjects at a specific place and time. In addition, temperature data (especially in the US) has been collected for many years, which allows researchers to calculate historical averages, long-term trends, and anomalies.

Previous research shows that the general public's perceptions of temperatures on the most recent day or two often reflects actual temperature conditions, suggesting that the general public is able to accurately assess very recent temperatures. Two studies in the US found that individuals' perceptions of whether the current day was warmer or colder than usual were positively correlated ($r = 0.24$ to 0.49) with actual temperature anomalies (Li et al., 2011; Zaval et al., 2014). One study also found that the previous day's perceived temperature anomalies were also significantly correlated with that day's actual temperature ($r = 0.26$) (Zaval et al., 2014). Furthermore, both studies found that perceptions of the current day's temperature were not correlated with the actual previous day's temperature, showing that individuals were able to consider conditions on the present day alone (Li et al., 2011; Zaval et al., 2014).

Public perceptions of recent seasonal temperatures tend to reflect actual conditions, meaning that individuals are also able to accurately assess temperatures over slightly longer periods and that seasonal temperatures are salient. In a 2012 study of the continental US, respondents in areas that had a warmer recent winters[2] were more likely to say that they had experienced a warmer than usual winter, compared to respondents who reported that the past winter had been colder than usual or about the same (standardized logistic coefficient = 0.92) (McCright, Dunlap, & Xiao, 2014). In a 2011 US survey, the probability of respondents perceiving the most recent winter or summer to have been warmer than normal were significantly related to increasing winter or summer temperatures, respectively (unstandardized b = 0.24 or 0.19, respectively) (Howe & Leiserowitz, 2013). The same study also found that respondents who reported a warmer than usual winter or summer did live in regions that had warmer local temperatures during the study, compared to respondents who said the winter or summer were normal or colder than usual.

There is mixed evidence for whether actual average temperatures for a year or more are significantly related to individuals' perceptions of temperatures over those longer time periods. In the 2007-2008 Gallup World Poll of 89 countries, individuals were more likely to report that temperatures in the local area had gotten warmer over the past 5 years (instead of having gotten colder or remained the same) as temperature anomalies for the previous year increased, assessed at either an individual respondent (logit coefficient = 0.29) or national level (logit coefficient = 0.48) (Howe et al., 2013). In another study, US surveys from 2008 to 2011 found no relationship between perceived temperature trends over the past few years and the actual change temperature over the past 3 years compared to a historical average, using an ordered logistic regression (Goebbert et al., 2012). Additionally, a survey of residents of the Gulf Coast region in 2011 found that seasonal temperature trends (over 10, 15, or 19 years) were largely not significantly related to perceptions of whether temperature had changed, us a logistic regression (Shao & Goidel, 2016). However, in the latter two studies, the time period was not specified in the survey question, so there may be a mismatch between the time period considered by study participants and the actual weather measured by the authors.

Two studies in the US found that perceptions of temperatures over longer time periods were also influenced by weather on the current day (Joireman et al., 2010; Zaval et al., 2014). One found that the temperature anomaly on the day of the study was significantly correlated ($r = 0.15$) with respondents' perceptions of the proportion of warmer-than-usual days over the past year (Zaval et al., 2014). The other found that the outdoor temperature at the time of the interview was significantly correlated ($r = 0.24$) with participants' perceptions of whether temperatures "seem warmer now than in years before" (Joireman et al., 2010). This suggests that recent weather is more influential in experiential processing of climate change than conditions further in the past, supporting the theory that psychologically closer experiences are more salient.

The accuracy of individuals' perceptions of recent short-term temperatures, compared to the inaccuracy of their perceptions of long-term temperatures, may be due to psychological distance. Since personal experience is psychologically close, then recent experiences (i.e., those with a short temporal distance) will be those that are most salient (Marx et al., 2007). Furthermore, perceptions of long-term temperatures seem to be influenced instead by more recent weather, meaning that perceptions of climate change could thus vary with the daily weather.

[2] The 2012 winter is climatologically defined as December, 2011 through February, 2012.

Perceptions of Precipitation

In contrast to temperature, precipitation experience is usually measured as extreme events (storms, hurricanes) or related impacts (flooding, drought) instead of direct measures (e.g., amount of rain and snow). This is likely due to precipitation data being much more limited, both spatially and temporally, and also to the higher variability in precipitation patterns. For example, Hamilton and Stampone (2013) attempted to estimate precipitation (daily total precipitation and occurrence of 1-inch events) across New Hampshire, but precipitation varied so greatly between the five available weather stations that the authors did not feel confident in estimating statewide precipitation (their level of analysis). In the same study the authors were confident in their estimates of statewide temperature, while using the same small sample of weather stations, because trends were more spatially consistent.

As a result, only one published study was found that examined the relationship between perceptions of precipitation trends and actual precipitation levels. In a 2011 US survey, Howe and Leiserowitz (2013) found that greater precipitation amounts increased the probability that respondents perceived the most recent winter or summer to have been wetter than normal (unstandardized $b = 1.08$ or 1.69, respectively). Additionally, respondents with similar climate perceptions had similar actual precipitation conditions: individuals who reported a wetter recent winter or summer had higher actual levels of precipitation compared to those who reported the same or dryer conditions (ANOVA, mean difference = 8.5% to 22.2%).

Perceptions of Overall Changes in Weather

Two studies were identified that examined the influence of actual weather on perceptions of overall changes in either weather or climate change, instead of on perceptions of specific types of weather. A 2007 study in the US found that neither actual temperature nor precipitation were related to the probability that respondents thought the weather had been stranger than normal over “in the past few years” (Shao, 2016). The actual weather was measured as seasonal anomalies over the past three years but the question about perceptions did not specify a time period, so respondents may have been considering weather over different time periods than the one measured by the researchers. A second study administered at the same time, focused on residents of rural areas in nine states, found that much longer trends (over 38 years) in temperature were significant predictors of the percent of respondents who perceived that there had been an effect of climate change on respondents’ families and communities (Hamilton & Keim, 2009). This latter study also examined seasonal temperature trends, finding that influence on perceptions of climate impacts was strongest for winter but similar for other seasons. These studies highlight the potential for individuals to perceive changes in overall weather and climate based on individual weather trends, in addition to perceiving changes in specific weather.

Methodological Implications of Quantifying Actual Weather Conditions

Most previous studies (described above) compared individuals’ perceptions of personal experience with weather or climate change to changes in weather over time. These measures of change are *relative* measures, meaning that they compare current to usual (“normal”) conditions, often expressed as trends or anomalies (deviations) from normal. When measuring perceptions of personal experience, the time period over which normal conditions are considered should represent a period that is short enough to have been experienced by many adults but long enough that it represents long-term trends. Studies generally used a historical average of 30 years, although some used as few as 15 years (Goebbert et al., 2012; Howe & Leiserowitz, 2013; Howe et al., 2013; McCright et al., 2014; Shao, 2016; Zaval et al., 2014). Several measured trends in weather using time periods of 10 to 38 years (Hamilton & Keim, 2009; Shao & Goidel, 2016).

Only one study was identified that did not use a relative measure, but instead used an *absolute* measure of temperature at the time of the survey with no context of normal or previous weather (Joireman et al., 2010).

The distinction between perceptions of absolute and relative weather may be important for understanding how individuals experientially process weather and climate change. However, no previous studies were identified that compared whether individuals' perceptions of personal experience were more related to absolute or relative weather measures. Since experiential processing is weighted toward recent experiences, this would suggest that perceptions might be more influenced by current or recent absolute weather conditions, such as feeling hot or cold in a certain moment. Perceptions of absolute conditions do not require an individual to remember previous conditions in order to understand whether the current situation is, for example, warmer or colder than usual. On the other hand, for individuals to conceptually link current or recent experiences to climate change, they would need to know if it is unusual or changed from normal, which would be a relative measure. If individuals are able to accurately perceive relative weather conditions, then their perceptions of climate change may match actual shifting patterns of weather and long-term climate trends.

Research Questions

This study evaluates the influence of recent weather on perceptions of climate change. In addition, this research will assess the influence of different types of weather to see which are the most relevant to experiential processing of weather and climate change. The questions also account for motivated reasoning perceptions of a polarized topic like climate change, which may limit the effect of experiential processing.

Research Question 1: Does recent weather influence perceptions of overall personal experience with climate change?

This analysis will examine weather on the current day and the preceding week. Previous studies have considered time periods of one to two days or much longer time periods (months to years), so this study uses a very recent time period (the current day) as well as a slightly longer time period that may still be memorable (the previous week).

- **Hypothesis 1.1**: Weather on the current day will predict perceptions of personal experience with climate change, controlling for motivated reasoning.
- **Hypothesis 1.2**: The average weather for the preceding week (the current day plus the six days before) will also predict perceptions of personal experience with climate change, controlling for motivated reasoning.

Research Question 2: Which types of recent weather most influence perceptions of overall personal experience with climate change?

The goal of this question is to understand what aspects of weather are most relevant to perceptions of personal experience.

- **Hypothesis 2.1**: Temperatures will more strongly predict perceptions of overall personal experience with climate change, controlling for motivated reasoning, compared to precipitation. While previous studies have often been unable to estimate local precipitation due to limited data, the influence of actual temperature on perceptions of personal experience with temperature has been well established.
- **Hypothesis 2.2**: Both relative measures of recent weather (i.e., percentiles of normal conditions) and absolute measures (i.e., degrees Fahrenheit or inches of precipitation)

will predict perceptions of overall personal experience with climate change, controlling for motivated reasoning. Previous research found that individuals are able to accurately perceive recent weather conditions and if they are different from usual. While there has been little research that measured perceptions of absolute weather conditions, absolute measures of weather may be salient to experiential processing because they only require that individuals assess current conditions instead of also accurately perceiving normal conditions.

Methods

This research focuses on New York State (NYS) because it is a state with diverse climate regions (see Figure 0.1), industries, and population demographics (Rosenzweig et al., 2011). As a result, members of the study population were exposed to a wide range of weather conditions and differed in their beliefs and perceptions of climate change. Focusing on only one state allowed the study to consider relatively consistent types of weather, as opposed to highly variable conditions across climate regions or the entire US.

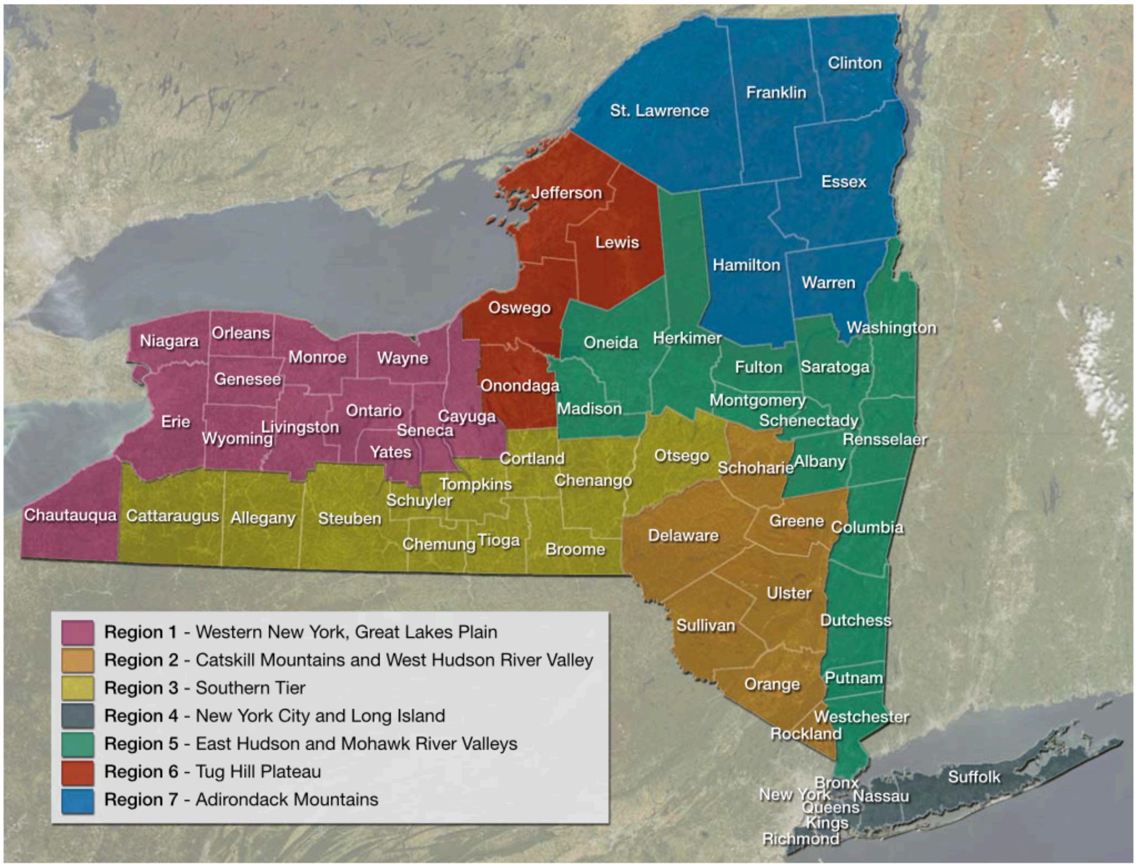

Figure 0.1 A map of New York State climate regions by the New York State Energy Research and Development Authority (Rosenzweig et al., 2011). Color-coding denotes seven climate regions, while white text and borders identify county boundaries and names.

Survey Methodology

Perceptions of personal experience with climate change were measured as part of the 2014 Empire State Poll (ESP), a telephone survey of adult (18 years and older) residents of NYS, conducted from January 18 through March 5, 2014. The final sample of completed surveys was 800 respondents, split evenly between downstate (9 counties in New York City and Long Island) and upstate (all other counties) to ensure a thorough sampling of upstate residents. Population-based sample weights based on 2009-2011 US Census data were applied such that the sample is representative of NYS residents (Xian & Meyers, 2014). Respondents' location was measured as their self-reported county of residence at the time of the survey. There were respondents from 61 of 62 NYS counties, and the 7 respondents who did not report their county of residence were removed from further analyses.

The Survey Research Institute at Cornell University administered the ESP as a dual-frame random digit dial telephone (land-line and cellular) survey. The sample was acquired from the Marketing Systems Group, and excluded known business telephone numbers, disconnected numbers, and non-households. Every listed telephone in NYS had an equal chance of being included in the survey; for each telephone number selected, the adult household member who was a resident of NYS and had the most recent birthday was selected to complete the survey, ensuring random selection of members within each household. The survey was administered in both English and Spanish.

The cooperation rate (the proportion of completed surveys out of all potential interviews, or instances where contact was made with an eligible respondent) was 66% and the response rate (the proportion of completed surveys out of the total eligible sample) was 21%; these rates are comparable to those obtained by other organizations that regularly survey NYS residents and the results of the 2009-2011 American Community Survey by the US Census (Xian & Meyers, 2014).

Study Measures

Respondents' perceptions of personal experience with climate change were measured as level of agreement with the statement "I have personally experienced the effects of extreme weather or climate change"[3] (response options were on a 5-point scale, from 1 = strongly

[3] Although this survey question combined perceptions of personal experience with both climate change and extreme weather, there is evidence that some (but not all) members of the general public respond similarly to questions about these topics: a 2015 national survey showed that perceptions of personal experience with climate change were

disagree to 5 = strongly agree). This question did not specify a time period and therefore represents overall or general perceptions of personal experience with climate change and extreme weather, rather than perceptions of specific weather events or trends over time.

Respondents' potential for motivated reasoning about climate change is related to pre-existing beliefs about the reality of climate change and how strongly those beliefs are held (Myers et al., 2013). Belief in climate change was measured with the question "Do you believe climate change is happening?" (response options were *yes*, *no*, or *don't know*).

Recent Weather

Recent weather was measured as temperature and precipitation in each respondent's county on the day of the survey and the week preceding the survey (the day of the survey through six days before that). To capture these time periods for all ESP respondents, weather data were collected for all days within the ESP administration period plus six days in advance. Daily weather data were obtained from the Northeast Regional Climate Center as a high-resolution (5 km x 5 km) grid, based on original data from the NOAA Regional Climate Center Applied Climate Information System. An example of one weather measure for a single day in a single county is shown in Figure 0.2a.

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significantly correlated to perceptions of personal experience with extreme weather (Pearson $r = 0.26$, $n = 998$, $p < 0.001$) (*unpublished data from the Cornell National Social Survey 2015*).

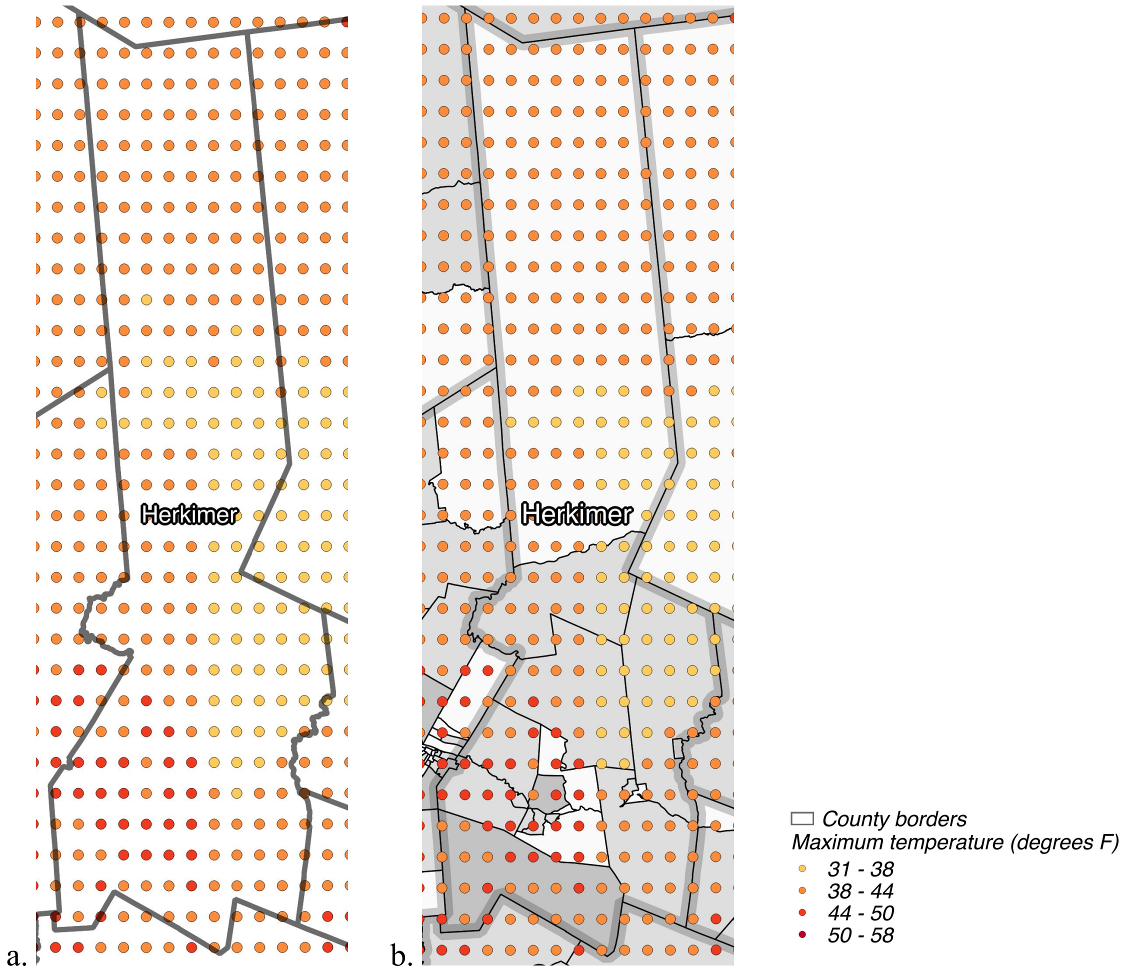


Figure 0.2 An example of gridded weather data from Northeast Regional Climate Center for Herkimer County, showing absolute maximum temperatures on January 7, 2014 as colored circles. Herkimer County is depicted in both a and b by the gray/black outline. Panel b also shows population (number of residents per each census tract), with darker gray shading indicating a larger population and thin gray lines marking census tract boundaries.

Types of weather included daily maximum and minimum temperatures and total daily liquid precipitation. This study defines two different ways of measuring weather: absolute measures (degrees Fahrenheit or inches of precipitation) and relative measures (percentile of the climate normal, statistical distribution of each weather measure over a historical time period). For the relative measures, a 30-year climate normal is generally used by climate scientists as a representative period experienced by an adult (Rosenzweig et al., 2011), so a 1981-2010 climate normal was used for temperature in this study. Precipitation data at the desired resolution were only available from 2002 on, so a 2002-2010 climate normal was used for relative precipitation measures in this study.

To match weather data to ESP respondents' locations, weather measures were aggregated at the county level. Since population density is not uniform (see Figure 0.2b), county averages were weighted by the population distribution. This calculation was performed in QGIS, an open-source Geographic Information System application, and Excel. Gridded weather data were imported into QGIS as points, and then linked to the county and census tract within which they were located (based on 2010 county and census tract shapefiles and population data obtained from the NYS GIS Clearinghouse). Figure 0.2b shows an example of one county's gridded weather data for a single day and 2010 census tract populations. Average weather measures for each census tract were calculated based on the mean of the internal grid points or, for census tracts smaller than the grid size, the value of the grid point nearest to the census tract center. Population-weighted census tract weather measures were calculated as the average weather measure for that census tract multiplied by the census tract's proportion of the county population. Final population-weighted county weather measures were computed as the sum of all population-weighted census tract weather measures within a county. All population-weighted county data were visually compared to original gridded data to verify accuracy.

Data Analysis

Population-weighted weather measures were matched to each ESP respondent using their county location and survey date for the day on which the survey was administered as well as the preceding six days. For example, the ESP was administered to one respondent in Albany on January 28, who was assigned the following weather measures: maximum temperature = 31.6 °F (percentile = 0.49), minimum temperature = 6.0 °F (percentile = 0.36), and precipitation = 0.02

in (percentile = 0.71); ESP was administered to three respondents in Albany on January 29, who were all assigned the following weather measures: maximum temperature = 17.0 °F (percentile = 0.08), minimum temperature = -0.1°F (percentile = 0.0), and precipitation = 0.0 in (percentile = 0.0).

Statistical analyses were performed in R to test the relationship between ESP respondents' perceptions of personal experience with climate change, recent weather, and climate change belief. Preliminary analyses included a visualization of weather measures using maps created in QGIS, and a Spearman correlation of ESP responses and recent weather measures. To answer Research Questions 1 and 2, multiple linear regressions were used to assess the influence of recent weather and climate change belief on respondents' perceptions of personal experience with climate change (the dependent variable). Perceptions of personal experience were treated as a 5-point continuous variable. A control model included only climate change belief as a predictor variable, while all other regression models included two predictor variables (climate change belief and one weather measure). Weather measures were centered for analyses, so that the regression intercepts represent the predicted perceptions of personal experience for ESP respondents who experienced the mean values of each weather measure. For all predictors included in multiple regression models, variance inflation factors were assessed to check for collinearity between predictor variables. In order for results to be representative of NYS as a whole, regression models used population-based sample weights to account for the ESP stratified random sampling method.

Results

Descriptive Results

ESP respondents generally believed that climate change is happening and that they had experienced it (Table 0.1). The majority of respondents (69%) agreed or strongly agreed that they had personally experienced the effects of extreme weather or climate change, while only 18% disagreed or strongly disagreed. An even larger proportion of respondents (81%) believed that climate change is happening. Only 4% of respondents said that they did not know whether climate change was happening, and were excluded from analyses. Table 0.1 shows how the 2014 ESP survey questions were coded for analyses.

Table 0.1 Descriptive results from the 2014 Empire State Poll

Survey question	Coding	Response options	Respondents (n)
Perceptions of personal experience	1	Strongly disagree	5% (39)
How much do you agree or disagree	2	Disagree	13% (101)
with the following statement: I have	3	Neutral	13% (103)
personally experienced the effects of	4	Agree	30% (240)
extreme weather or climate change	5	Strongly agree	39% (310)
Climate change belief	0	No	15% (118)
Do you believe that climate change is	1	Yes	81% (645)
happening?	-	Do not know	4% (30)

Table 0.2. Descriptive results of weather measures for 2014 Empire State Poll respondents on the day of and the week preceding survey administration. Data for each respondent are population-weighted county averages calculated in this study, based on original data from the Northeast Regional Climate Center. N = 763.

Weather Type	Absolute measures (degrees F)		Relative measures (percentile of normal*)	
	Range	Mean	Range	Mean
Day of the survey				
Maximum temperature	0.35, 56.2	32.5	0, 0.90	0.32
Minimum temperature	-18.6, 36.6	14.9	0, 0.91	0.32
Precipitation	0, 1.29	0.06	0, 0.97	0.30
Week preceding the survey				
Maximum temperature	11.8, 47.0	32.7	0.07, 0.86	0.34
Minimum temperature	-16.6, 31.6	15.8	0.06, 0.86	0.36
Precipitation	<0.01, 0.35	0.11	0.01, 0.77	0.40

*Normal refers to the historical distribution of weather measures, from 1981-2010 (temperature measures) or 2002-2010 (precipitation measures)

During the 3-month study period, respondents experienced a wide range of temperatures and precipitation amounts (Table 0.2). Daily absolute maximum and minimum temperatures ranged from below to above freezing, which was within the range of normal temperatures for that period of late winter through early spring, as shown by the relative measures. Daily absolute precipitation amounts were generally very small, and the few days of >1 inches of precipitation were not unusual (within the 97th percentile). Weekly average temperatures and precipitation were similar to daily values.

Figure 0.3 shows maps for weather measures on a single day during the ESP, as an example of how absolute and relative measures of weather can differ. These maps do not represent the conditions experienced by all respondents, because survey dates varied for each respondent over the 3-month survey implementation period. On the day pictured, the warmest maximum temperatures (both absolute and relative) occurred in the Catskill Mountains and West Hudson River Valley, the East Hudson and Mohawk River Valleys, the Adirondack Mountains, and the New York City and Long Island regions. The warmest absolute minimum temperatures on that day also occurred around New York City and Long Island, the East Hudson and Mohawk River Valleys, and the Adirondack Mountains; however, the warmest relative minimum temperatures were only in the northern portion of that range (the Adirondack Mountains, the East Hudson and Mohawk River Valleys, and the Tug Hill Plateau), while New York City and Long Island had cooler relative minimum temperatures.

The highest absolute precipitation amounts occurred in the New York City and Long island, the Catskill Mountains and West Hudson River Valley, and a portion of the Great Lakes Plain regions. This was much more spatially scattered than the relative precipitation amounts, which were consistently located in the eastern part of the state (New York City and Long Island, the Catskill Mountains and West Hudson River Valley, part of the East Hudson and Mohawk River Valleys, and the Adirondack Mountains regions).

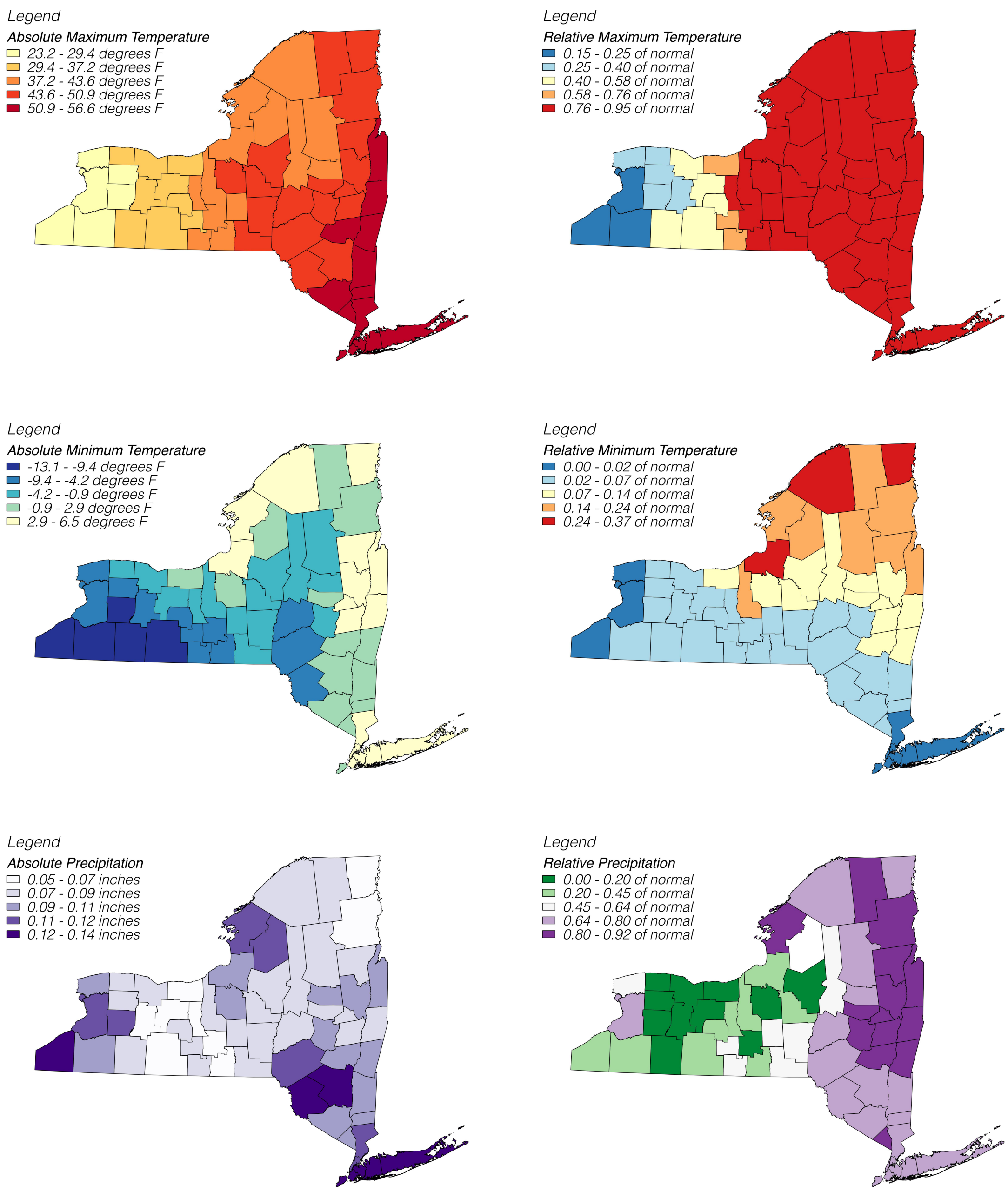


Figure 0.3. Maps of New York State for all study weather measures on January 7, 2014, measured as population-weighted county averages. Original data were obtained from the Northeast Regional Climate Center.

Motivated Reasoning

A majority of respondents who believed that climate change is happening (76%) also agreed or strongly agreed that they had personally experienced the effects of climate change or extreme weather (Table 0.3). Some climate change believers (12%) disagreed or strongly disagreed that they had personally experienced climate change or extreme weather (Table 0.3). Respondents who did not believe in climate change were evenly divided in their perceptions of personal experience: for non-believers in climate change, 41% agreed or strongly agreed that they had personally experienced the effects of climate change or extreme weather while 43% disagreed or strongly agreed. This suggests that individuals who believe in climate change are more likely to say that they have experienced the effects of climate change or extreme weather.

Table 0.3 2014 Empire State Poll respondents' perceptions of personal experience with the effects of extreme weather or climate change, as a percentage (number) of respondents who believe or do not belief that climate change is happening.

Perceptions of personal experience	**Climate change belief**	
	Yes (n = 645)	No (n = 118)
Strongly disagree	2% (20)	16% (19)
Disagree	10% (64)	27% (32)
Neutral	11% (72)	18% (21)
Agree	31% (201)	25% (30)
Strongly agree	45% (291)	16% (19)

Respondents' perceptions of their personal experience with the effects of extreme weather and climate change were significantly correlated with their belief in climate change (Table 0.4 and Table 0.5). The correlation was positive, meaning that belief in climate change (as opposed to not believing that it is happening) was related to an increase in perceptions of personal experience. Belief was not significantly correlated with any of the weather measures.

Similarly, in a linear regression model, belief was a significant predictor of perceptions of personal experience (Table 0.6 and Table 0.7). The intercept for this control model was 3.10, meaning that the average respondent who did not believe in climate change was predicted to neither agree nor disagree with the statement that they had personally experienced the effects of extreme weather or climate change. The unstandardized beta for belief was about 1.0, meaning that respondents' perceptions of personal experience shifted by 1 point (on the 5-point scale): a respondent with the average value for any weather measure who *did* believe in climate change was predicted to agree (but not strongly agree) with the statement that they had personally experienced the effects of extreme weather or climate change. The variance in perceptions of personal experience explained by climate change belief (adjusted R^2) was about 8%.

Research Question 1: Does recent weather influence perceptions of overall experience with climate change?

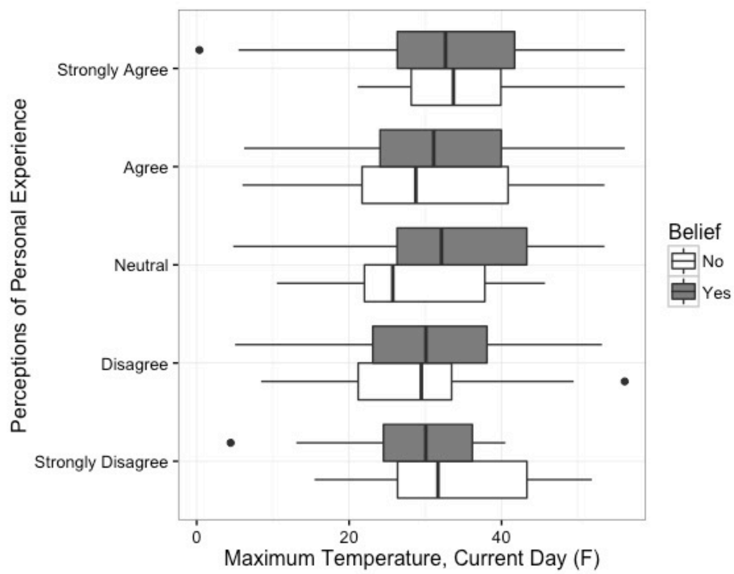
Both Hypothesis 1.1 and Hypothesis 1.2 were supported, as some weather measures for the day of and the week preceding survey administration were significantly related to respondents' perceptions of personal experience. Absolute maximum and minimum temperatures for both time periods were significantly correlated with perceptions of personal experience (r_s = 0.10 to 0.13) (Table 0.4 and Table 0.5). All weather measures were significantly correlated with each other, with the highest correlations between maximum and minimum temperatures (r_s = 0.66 to 0.88) and lowest correlations between either type of temperature and precipitation (r_s = 0.10 to 0.27). Correlation results using weather for the week prior to the survey were similar to those for the single day weather (Table 0.5). Due to the collinearity of the weather measures, regression models only included one weather measure at a time.

In multiple linear regressions models including climate change belief, absolute maximum and minimum temperature for both time periods were significant predictors of perceptions of personal experience (Table 0.6 and Table 0.7). No other weather measures were significant predictors of personal experience. For absolute maximum and minimum temperatures (both for the day of and the week preceding the survey), beta coefficients were positive, meaning that respondents agreed more that they had experienced the effects of extreme weather or climate change as local maximum and minimum temperatures increased. The standardized beta coefficients for these two weather measures (0.07 to 0.11) were less than those for climate change belief (about 0.30), meaning that weather had a smaller influence on perceptions of personal experience than did climate change belief. There was a wide spread of both absolute minimum and minimum temperatures among respondents who gave each response about perceptions of personal experience, but respondents who agreed more that they had personally experienced the impacts of climate change tended to have higher average temperatures (Figure 0.4 shows data for the day of the survey for both maximum and minimum temperature).

Research Question 2: Which types of recent weather most influence perceptions of overall personal experience with climate change?

Hypothesis 2.1 was supported, as both maximum and minimum temperatures were significant predictors of respondents' perceptions of personal experience, but precipitation was not. While there was wide variation in both minimum and maximum temperatures, precipitation amounts were generally very low, with a few high (but not extreme) levels. As a result, there may not have been enough statistical power to detect a trend for precipitation over the time periods used in this study.

Hypothesis 2.2 was partly supported, as only absolute weather measures were significant predictors of perceptions of personal experience. While absolute and relative measures were significantly correlated with each other for both maximum and minimum temperature (Table 0.4 and Table 0.5), the maps in Figure 0.3 illustrate that these measures are not identical, and therefore only absolute measures being a significant predictor is unlikely to be a statistical artifact. This is further supported by consistent results between the correlation and regression analyses: of the weather measures, only absolute maximum and minimum temperatures were significantly correlated with or significant predictors of perceptions of personal experience.



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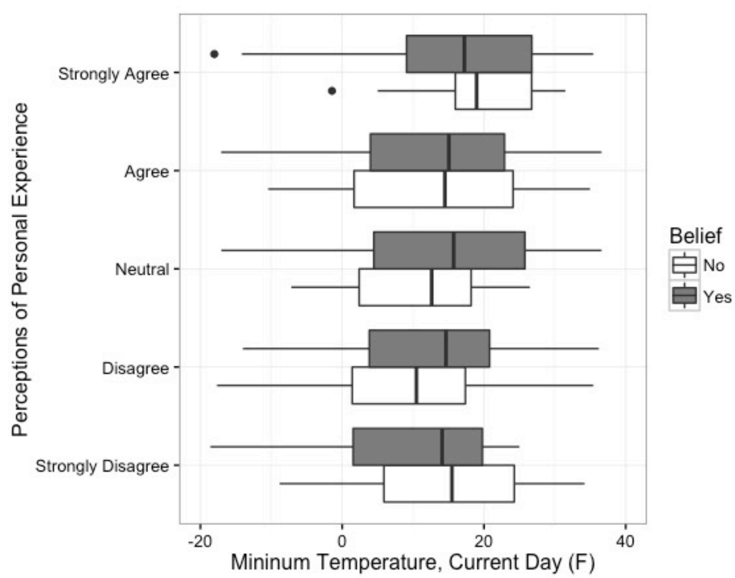

b.

Figure 0.4 Respondents' agreement that they had experienced the effects of extreme weather or climate change as a function of the local absolute maximum (a) and minimum (b) temperatures on the day of the survey. Filled bars represent respondents who believed that climate change is happening, while empty bars represent respondents who do not believe in it.

Table 0.4. Correlation matrix between 2014 Empire State Poll respondents' perceptions of personal experience with climate change or extreme weather and climate change belief, and weather conditions in their county on the day of the survey administration. Data are presented as the Spearman correlation coefficient.

	Personal experience (n = 769 [belief], 793)	Climate change belief (n = 763)	Absolute maximum temperature (n = 793)	Relative maximum temperature (n = 793)	Absolute minimum temperature (n = 793)	Relative minimum temperature (n = 793)	Absolute precipitation (n = 793)
Climate change belief	0.30*						
Absolute maximum temperature	0.11*	0.06					
Relative maximum temperature	0.05	0.02	0.82*				
Absolute minimum temperature	0.13*	0.06	0.88*	0.68*			
Relative minimum temperature	0.07	0.02	0.66*	0.79*	0.79*		
Absolute precipitation	-0.05	-0.05	0.11*	0.24*	0.15*	0.27*	
Relative precipitation	-0.04	-0.04	0.10*	0.23*	0.14*	0.25*	0.99*

*p < 0.05

Table 0.5. Correlation matrix between 2014 Empire State Poll respondents' perceptions of personal experience with climate change and climate change belief, and average weather conditions in their county for the week preceding survey administration. Data presented as the Spearman correlation coefficient.

	Personal experience (n = 769 [belief], 793)	Climate change belief (n = 763)	Absolute maximum temperature (n = 793)	Relative maximum temperature (n = 793)	Absolute minimum temperature (n = 793)	Relative minimum temperature (n = 793)	Absolute precipitation (n = 793)
Climate change belief	-0.30*						
Absolute maximum temperature	0.10*	0.05					
Relative maximum temperature	0.00	0.00	0.63*				
Absolute minimum temperature	0.12*	0.06	0.94*	0.50*			
Relative minimum temperature	0.00	0.01	0.68*	0.83*	0.67*		
Absolute precipitation	-0.01	0.01	0.25*	-0.11*	0.34*	0.24*	
Relative precipitation	0.02	0.02	0.51*	0.20*	0.54*	0.44*	0.69*

*p < 0.05

Table 0.6. Linear regression models predicting 2014 Empire State Poll respondents' perceptions of personal experience with the effects of climate change or extreme weather as the dependent variable. Predictors include respondents' belief in climate change and weather measures in respondents' counties for the *day of the survey*. Data presented as unstandardized *B* coefficients (standard errors) and standardized *β* coefficients.

	Model 1 (Belief)		Model 2 (AMax)		Model 3 (RMax)		Model 4 (AMin)		Model 5 (RMin)		Model 6 (AP)		Model 7 (RP)	
	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β
Intercept	3.10** (0.11)	0	3.07**		3.10**		3.07**		3.08**		3.07**		3.08**	
Climate change belief	0.98** (0.12)	0.29	0.99** (0.11)	0.30	0.97** (0.12)	0.29	0.98** (0.12)	0.29	1.00** (0.12)	0.30	1.00** (0.12)	0.30	1.00** (0.12)	0.30
Absolute maximum temperature (AMax)			0.01* (0.01)	0.08										
Relative maximum temperature (RMax)					0.20 (0.16)	0.04								
Absolute minimum temperature (AMin)							0.01* (0.01)	0.11						
Relative minimum temperature (RMin)									0.32 (0.17)	0.07				
Absolute precipitation (AP)											0.22 (0.31)	0.02		
Relative precipitation (RP)													-0.14 (0.12)	0.04
Adjusted R^2	0.083		0.092		0.083		0.096		0.090		0.086		0.087	
p-value	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
df	761		760		760		760		760		760		760	

*p < 0.05, **p < 0.001

Table 0.7. Linear regression models predicting 2014 Empire State Poll respondents' perceptions of personal experience with the effects of climate change or extreme weather as the dependent variable. Predictors include respondents' belief in climate change and average weather measures in respondents' counties for the *week preceding the survey*. Data presented as unstandardized *B* coefficients (standard errors) and standardized *β* coefficients.

	Model 1 (Belief)	Model 2 (AMax)		Model 3 (RMax)		Model 4 (AMin)		Model 5 (RMin)		Model 6 (AP)		Model 7 (RP)	
	B (SE)	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β
Intercept	3.10** (0.11)	3.07**		3.07**		3.07**		3.07**		3.07**		3.08**	
Climate change belief	0.98** (0.12)	0.99** (0.12)	0.30	1.00** (0.12)	0.30	0.99** (0.12)	0.30	1.00** (0.12)	0.30	1.00** (0.12)	0.30	1.00** (0.12)	0.30
Absolute maximum temperature (AMax)		0.01** (0.01)	0.07										
Relative maximum temperature (RMax)				-0.22 (0.29)	-0.03								
Absolute minimum temperature (AMin)						0.01* (0.00)	0.08						
Relative minimum temperature (RMin)								-0.41 (0.30)	-0.05				
Absolute precipitation (AP)										-0.00 (0.43)	<0.01		
Relative precipitation (RP)												0.08 (0.26)	0.01
Adjusted R^2	0.083	0.089		0.086		0.091		0.087		0.085		0.085	
p-value	<0.001	<0.001		<0.001		<0.001		<0.001		<0.001		<0.001	
df	760	760		760		760		760		760		760	

*p < 0.05, **p < 0.001

Discussion and Future Research

Experiential Processing of Weather and Climate Change

Overall, results support this study's hypotheses and previous studies' findings (Hamilton & Keim, 2009; Joireman et al., 2010; Zaval et al., 2014) that recent weather can influence the public's perceptions of personal experience with overall weather or climate change. Although two weather measures significantly influenced perceptions of personal experience, the influence of weather was much smaller than that of climate change belief. The fact that recent weather can influence overall climate perceptions at all shows how strongly the experiential processing of climate is weighted towards recent events. Results were similar for weather on the day of and week preceding survey administration, suggesting that the recency bias of experiential processing applies to time periods of up to one week. The influence of short-term on individuals' perceptions of long-term trends, may be partly explained by findings that the general public often confuses weather and climate (Reynolds et al., 2010). It also suggests that experiential processing of psychologically distant phenomena, such as long-term global climate change, are disproportionately affected by psychologically close events.

This study also examined which types of weather matter most in experiential processing of climate change, by assessing which types of weather influenced perceptions of personal experience with climate change and extreme weather. Results in this study that recent temperature was a significant predictor of perceptions of personal experience supports previous similar studies (Hamilton & Keim, 2009; Joireman et al., 2010; Zaval et al., 2014). The ESP was administered during winter and early spring months, which may be a time when temperatures are particularly salient: other studies found that the general public has reported experiencing warmer winters in recent years and associates such changes with climate change (Akerlof et al., 2013; Hamilton & Keim, 2009; Howe & Leiserowitz, 2013). This study examined both absolute minimum and maximum temperatures because, for the general public, those are often associated with different parts of the day (night and day, respectively) and therefore may be experienced under different circumstances (trying to sleep at home and often out during the active part of the day, respectively). However, results were similar for these two measures, which is not surprising as trends in temperature were similar between the maximum and minimum measures.

While precipitation was not a significant predictor of perceptions of personal experience, the range of precipitation amounts during the study period was very small, which likely limited its possible influence on perceptions. The findings of this study are not conclusive with regards to precipitation, and therefore it is recommended that future studies consider a location or a time of year that will have a wider range of precipitation levels. Only two previous studies were identified that assessed precipitation as a predictor of self-reported personal experience: one found that higher amounts of winter and summer precipitation increased the probability that respondents perceived those seasons as having been wetter-than-usual (Howe & Leiserowitz, 2013), while the other did not find a significant correlation between respondents' perceptions of overall weather strangeness in the past few years compared to normal and actual seasonal precipitation levels (Shao, 2016). Few previous studies were able to estimate local precipitation due to limited data availability and increased variability in precipitation patterns (Hamilton & Stampone, 2013). This variability could also make it harder for individuals to think about long-term trends, or prevent them from seeing precipitation conditions as associated with climate change. Other studies have found that perceptions of precipitation may instead be influenced by actual precipitation when the extreme impacts of precipitation are considered, such as storms, flooding, drought (Akerlof et al., 2013; Goebbert et al., 2012; Howe et al., 2014; Shao & Goidel, 2016). The next chapter of this thesis addresses the influence of such extreme events on perceptions of personal experience.

This study also raised the question of how individuals experience weather: in comparison to normal or past weather (relative measures), or just based on how conditions seem at the moment (absolute measure). Previous studies show that individuals could accurately perceive relative temperatures and precipitation over periods of up to 10 years, as described in the Literature Review. However, this study's results suggest that individuals also respond to absolute weather, as absolute weather measures were significant predictors of perceptions of personal experience in this study. While absolute and relative temperatures were similarly spatially distributed (Figure 0.3) and highly correlated (Table 0.4 and Table 0.5), there were some areas in which there were key differences; for example, New York City had some of the warmest absolute minimum temperatures but some of the lowest minimum temperatures. Due to the recency bias in perceptions of personal experience, the general public may have a hard time remembering what "normal" conditions should be, and therefore not understand how current conditions relate to changes in weather and climate.

It should be acknowledged that it is challenging for researchers to estimate the actual weather experienced by respondents, in order to compare these to individuals' perceptions of weather and climate. An individuals' experience with weather depends on their exact location and whether they have access to a climate-controlled environment, such as a car or office. As a result, average meteorological measurements over an area (such as an entire county) do not necessarily capture the entire weather exposure of any specific individual. Nevertheless, this study attempted to best represent the average weather that individuals in each county might be exposed to by calculating population-weighted weather averages instead of raw averages. Future studies that are able to identify the location of their respondents at a higher resolution (e.g., zip code) will be calculating average weather over a smaller area, and therefore may not need to considering population-weighting their weather measures. However, over large areas (e.g., at the state or national level), population weighting should be considered to better estimate the weather experienced by the average respondent. Furthermore, meteorological conditions do not necessarily translate into impacts felt by weather: for example, heavy rains may not result in flooding, or a hot but dry day may not feel uncomfortably hot if it is not humid. Future studies might consider certain thresholds of weather that would impact individuals, such as high temperatures above a heat index, a late spring frost, or heavy rains that may cause erosion or flooding.

Motivated Reasoning

This study's results that climate change belief was a significant predictor of perceptions of personal experience with extreme weather or climate change support previous findings that belief in climate change influences perceptions of personal experience (Myers et al., 2013). Motivated reasoning helps explain the way in which respondents in this study who believed in climate change were more likely to interpret weather experiences (regardless of actual conditions) as representing climate change or extreme weather, in order to support their belief that climate change is happening. The possibility for an interaction between the effects of motivated reasoning (possibly stemming from climate change belief) and actual weather on perceptions of personal experience indicates that future studies should include both variables concurrently in analyses.

A higher percentage of respondents in this study (69%) reported having personally experienced the effects of extreme weather or climate change, compared to 34% of respondents in a national survey also conducted in early 2014 (Leiserowitz et al., 2017). Similarly, a larger proportion of respondents in this study (81%) believed that climate change was happening, compared 64% of respondents in that national survey (Leiserowitz et al., 2017). While the results of this analysis are representative of NYS, the aforementioned differences suggest that NYS residents are perhaps a unique population with regard to the strength of their climate change beliefs and self-reported personal experiences with climate change and extreme weather. The influence of belief in climate change on perceptions of personal experience through motivated reasoning suggests that the large proportion of respondents in this study who believe in climate change may be partly responsible for the many who reported personal experience with climate changes' effects.

Other Considerations

Perceptions of personal experience with weather or climate change may also be shaped by factors other than actual weather conditions and individuals' climate change beliefs. The literature on social-psychological formation of climate change perceptions suggests that additional pressures may come from media attention, communication by thought leaders such as politicians, and other social groups based on ideology, political party, and socio-demographics (Akerlof et al., 2013; Brulle, Carmichael, & Jenkins, 2012; Deryugina, 2013; Donner & McDaniels, 2013; Egan & Mullin, 2012; Goebbert et al., 2012; Howe & Leiserowitz, 2013; Joireman et al., 2010). Many of these spatial factors may be dependent on location, such as local news media and advocacy groups. Additionally, social and climatological variables may be correlated: for example, in this study the warmest temperatures also tended to be around New

York City, which also has the highest proportion of residents who believe that climate change is happening (Howe, Mildenberger, Marlon, & Leiserowitz, 2015). Future studies with sufficient statistical power should control for these potential dependencies, either through multi-level analyses that includes respondents' location (e.g., Cutler, 2015) or through explicit assessment of spatial dependencies.

Conclusion

This research suggests that experiential processing of the public's personal experience with climate change may be swayed by short-term weather conditions. Although a small effect, weather fluctuations on a single day or a week are still highly weighted in a lifetime of experiences with weather or, over a long enough time, climate change. These findings support the theory of psychological distance, as close (recent) situations were able to influence perceptions of a long-term phenomenon. As a result, perceptions of personal experience with climate change may vacillate as daily, yearly, and decadal weather patterns pass through. This may have implications for how individuals feel concern about or take action on climate change: cooler weather might reduce the public's perceptions of climate change impacts, while hot days might increase perceptions. Depending on the timing of certain weather conditions compared to other events (surveys, political campaigns, or consumer decisions), individuals' responses may differ. Over a period of thirty years or more, perceptions of personal experience with climate change may consistently recognize the impacts, but then it may be too late to alter risk perceptions and effect a response.

This research also supports previous literature that suggests perceptions of personal experience are largely perceived through the lens of existing views on climate change (Dunlap et al., 2016; Myers et al., 2013). Therefore, weather conditions and events will be interpreted through motivated reasoning, based on climate change beliefs, worldviews, and other sources of information. Experiential processing may interact with these social factors, with some individuals more open to changing their minds based on their experiences.

To promote mitigation and adaptation action on climate change in the general public, it is important to understand how the weather may further or hinder perceptions of climate impacts. These results may then be connected to work on how perceptions may lead to climate action, or what prevents this (Akerlof et al., 2013; Brügger et al., 2015; Myers et al., 2013; Shao, 2016). As certain populations may resist taking in new information, instead using motivated reasoning to support their existing beliefs, it is also valuable to know which climate change views or sociodemographic characteristics are most associated with motivated reasoning compared to experiential processing (and learning through more traditional education and communication methods).

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CHAPTER 2

THE INFLUENCE OF EXTREME WEATHER EVENTS ON PERCEPTIONS OF PERSONAL EXPERIENCE WITH CLIMATE CHANGE AND EXTREME WEATHER

Abstract

As climate change alters the frequency of extreme weather events, there is the potential for the general public to gauge personal impacts of climate change through these events. Known as experiential processing, this psychological mechanism describes the way in which people shape their understanding of a topic through personal experiences. For any person, local extreme weather events are typically rare but highly salient and emotional, which can cause perceptions of experience to vary greatly based on whether an event has occurred recently or not. This study examines how New York State adults' perceptions of personal experience with climate change and extreme weather in early 2014 are related to the frequency of the following recent local extreme weather events: 1) winter weather and extreme cold events, and 2) flood events. Results suggest that a decreasing frequency of winter weather and extreme cold events are associated with greater perceptions of personal experience, as this reflects the public's understanding of climate change being manifested as warming temperatures. This study also accounts for the influence of the existing belief that climate change is happening on respondents' perceptions, as it can cause individuals to interpret events in a way that reinforces their previous beliefs (motivated reasoning).

Introduction

Across the US, climate change has increased the frequency and intensity of various extreme weather events such as heat waves, heavy downpours, inland and coastal flooding, wildfires, droughts, and severe storms (Melillo et al., 2014). Such events bring attention to the topic of climate change, increasing its salience to the public. For example, during Hurricane Sandy in 2012 – one of the largest Atlantic Hurricanes on record, with extensive storm surge upon landfall in the northeast US that caused 150 deaths and at least $50 billion in damages (Blake et al., 2013) – there was a spike in both mass media and social media (Twitter) mentions of the words “climate change” and “global warming” (Cody, Reagan, Mitchell, Dodds, & Danforth, 2015; Kirilenko, Molodtsova, & Stepchenkova, 2015; Kryvasheyeu et al., 2015). This lasted past the immediate impacts of Hurricane Sandy: even after Twitter users stopped discussing the word “hurricane,” they still discussed “climate” more than they had before the event (Cody et al., 2015).

Climate change views may be impacted by perceptions of extreme weather events of multiple types. For example, a 2011 survey of farmers in the CA Central Valley found that belief in and concern about climate change were significantly related to the perception that local past water availability had decreased over their farming career (Haden, Niles, Lubell, Perlman, & Jackson, 2012). Similarly, a telephone interview of US adults from 1997-1998 found that belief in climate change was higher for individuals who said that winter and summer temperatures in their local area had changed in recent years (Krosnick, Holbrook, Lowe, & Visser, 2006). Following widespread flood events in 2007 and 2009 in the UK, interviews in 2010 found that individuals who reported experiencing flooding were more certain that climate change exists and more concerned about its impacts compared to individuals who had not experienced flooding (a. Spence, Poortinga, Butler, & Pidgeon, 2011).

These perceptions of changes in weather may be shaped by personal experience with extreme weather impacts. For example, a 2013 online survey in the UK found that respondents were significantly more likely to report that the number of hot-weather events (heat waves, hot summers, and dry periods without rain) was increasing when they had personally faced heat wave-related impacts (discomfort, water restrictions, disrupted transportation, or illness) (Taylor et al., 2014). Respondents who had experienced flooding in their area were more likely to perceive increases in wet-weather events, including flooding, periods of heavy rainfall, and coastal erosion (Taylor et al., 2014). Furthermore, in a 2007 survey in Michigan and Pennsylvania, 40% of respondents said their view of whether the Earth was getting warmer was affected by warmer local temperatures in recent years (Borick & Rabe, 2010). On the other hand, respondents generally reported that Hurricane Katrina, which occurred in the Gulf Coast region of the US, did not affect their belief in global warming (Borick & Rabe, 2010); since Hurricane Katrina was further away, this suggests that nearby personal weather events were influential while more distant events were not.

Although the frequency of extreme weather events is increasing with climate change, a single extreme event cannot be directly attributed to or equated with climate change (Melillo et al., 2014). However, the general public tends to confuse weather and climate (Reynolds et al., 2010), making it likely that such misattributions will occur. The psychological theory of experiential processing explains how extreme weather events (as opposed to long-term, global climate change), by virtue of being vivid and recent, can cause individuals to associate their recent personal experiences with climate change (Weber, 2010). The literature review will discuss the process of experiential processing, and review previous research on how experiences with different types of extreme weather shape perceptions. This study, focused on adults in New York State, will then compare how different types of extreme weather events affect respondents' perceptions of personal experience extreme weather and climate change, to evaluate which types of extreme weather may be most influential in experiential learning.

Literature Review

To understand how individuals' personal experience with extreme weather can shape their perceptions of these events and of climate change, this section will review the psychological theory of experiential processing. Extreme weather events are rare but often highly salient, so this section will discuss how these characteristics bias psychological processing, drawing on the theory of psychological distance and the risks-as-feelings hypothesis. As climate change is a controversial topic this review also recognizes other forces shaping perceptions and beliefs, which can limit experiential processing through motivated reasoning, or the interpretation of any information in such a way that it upholds preconceived perceptions and beliefs. Following this theoretical background, the next section will summarize previous research on the relationship between different types of extreme weather events and the general public's perceptions of extreme weather and climate change. After identifying knowledge gaps, research questions motivating this study will be presented.

Psychological Processing

The mechanism by which people comprehend their experiences with extreme weather events and conceptually link these to perceptions of climate change can be explained by the psychological theory of *experiential processing*, which refers to an unconscious method of understanding new information by comparing it to previous situations or experiences (Epstein, 1994; Sloman, 1996). Experiential processing is characterized by vivid and emotional associations (Epstein, 1994; Loewenstein et al., 2001; Weber, 2010), and so extreme weather events – which tend to be visible, salient, and publicized – are likely to be understood through this process (Marx et al., 2007; Weber & Stern, 2011).

This is in contrast to a complementary method of cognitive evaluation, *analytical processing*, which is defined by conscious, logical reasoning and allows individuals to articulate abstract and symbolic ideas (Epstein, 1994; Loewenstein et al., 2001; Sloman, 1996). Analytical processing would seem necessary for understanding extreme weather events, which are uncommon for a particular location and often defined based on a statistical distribution of normal weather (IPCC, 2014). While people generally rely on both methods of processing, analytical information is often overwhelmed by experiential: for instance, individuals hearing about the experience of a single person in a vivid account tend to rate a risk as higher than those who hear about the same risk in terms of statistical probabilities (Marx et al., 2007; Sloman, 1996). This is even more so the case for complex situations, such as risky gambling scenarios or the spatially and temporally variable impacts of climate change (Lejarraga, 2010; Loewenstein et al., 2001; Marx et al., 2007; Weber et al., 2004).

However, extreme weather impacts, by virtue of their salience and rarity, will bias perceptions formed through personal experience. Because extreme events are unusual, much of the time the average person is not affected by any events. However, when an individual has a non-zero risk of an event occurring, but it hasn't happened to them yet, they increasingly tend to disregard the probability that it will ever happen (Hertwig et al., 2012; Yechiam et al., 2005). This phenomenon can be described by Kahneman and Tversky's *prospect theory*, in which uncertain events are underweighted in comparison to certain events (1979). For climate change risks, this might come in the form of discounting the impacts of future possible severe storms on a coastal community in comparison to the certain present costs of relocating to a “safer” location.

Conversely, once a rare event occurs it will be over-weighted in experiential processing. Personal experience is a vivid and emotional processing mechanism, and the impacts of extreme weather are often very striking, meaning that experience with extreme weather events may greatly influence perceptions of weather and climate. Emotional associations with extreme weather events have been found to increase the level of risk that individuals perceive (Keller et al., 2006). Loewenstein et al. (2001) articulate this as the *risk-as-feelings hypothesis*, or the tendency for individuals to respond based on their emotions instead of on a cognitive evaluation of risk probabilities. Personal experience with extreme events can also disproportionately influence perceptions of climate change right after they happen, as recent memories have the strongest influence on overall perceptions (Hertwig et al., 2012; Marx et al., 2007). The over-weighting and under-weighting effects of personal experience with extreme weather events can cause volatility in climate change perceptions (Weber & Stern, 2011).

Furthermore, extreme weather events are commonly reported by the news media, often accompanied by visual and emotional stories. One of the most common topics of climate-related news is severe weather events, especially those that are extraordinary and have a large impact (Olteanu, Castillo, Diakopoulos, & Aberer, 2015). Mass media coverage of climate change from 2002 to 2010 in the US (including major broadcast television networks, newspapers, and news magazines) was found to significantly increase public concern about climate change from national surveys over that period (Brulle et al., 2012). Similarly, in a 2012 survey of US Gulf Coast residents, perceptions that extreme weather events were becoming more frequent and concern about future climate change impacts were significantly higher in individuals who reported getting information about climate change from traditional news media (including television news and newspapers) (Shao & Goidel, 2016). These studies suggest that news media increase the salience of extreme weather events through reporting on them, and that coverage often portrays these events as evidence for climate change.

There is evidence that extreme weather events more strongly influence perceptions of personal experience than do more normal weather conditions. In US surveys from 2003 to 2010, belief that climate change was happening and that its effects had already begun was significantly related to local extreme temperature anomalies for 2 weeks to 6 months; this relationship was more significant when higher extremes were used (e.g., temperatures about the 95^{th} quantile instead of about the 75^{th} quantile) (Deryugina, 2013). Extreme weather can also be considered as a longer period of unusual conditions: in a study of the US general population, the percent of respondents who believed that the earth was getting warmer was significantly higher for those who had experienced a heat wave (temperatures at least 10 degrees Fahrenheit above normal for seven or more days in a row) compared to respondents who had experienced the same number of extremely hot temperatures spread out over three weeks (Egan & Mullin, 2012).

However, psychological processing may be limited because new information is filtered through existing ideas. According to the *cultural cognition thesis*, individuals generally adhere to the values of the groups with which they identify (Kahan et al., 2012; Kahan, Jenkins-Smith, & Braman, 2011), and prevent new information from changing pre-existing beliefs. This leads to a process called *motivated reasoning*, in which new information is not ignored, but instead interpreted in a very specific way to bolster existing beliefs and views (Chen et al., 1999; Myers et al., 2013). Previous research has suggested that this process occurs with experiential processing of climate change: individuals with stronger beliefs that climate change was happening or that are more concerned about climate change are more likely to report having experienced climate change or unusual weather (Myers et al., 2013; Shao, 2016).

Perceptions of Personal Experience with Climate Change

The next sections will review previous studies on the congruence between perception and reality: how the occurrence of extreme weather events influences perceptions of personal experience with those events, changes in weather, and climate change. The review is divided into sections based on the types of extreme weather found in the literature: extreme temperatures, storm events, flood events, drought events, and indices of overall extreme weather.

The population of interest for this study is the general public in developed countries, so the actual weather types are those that the public associates with climate change. In a 2003 UK study, when asked what impacts climate change would have if it happened, respondents' top three answers were changes or extremes in weather, flooding, and sea level rise or loss of land (Whitmarsh, 2008). Similarly, in a US study in 2002-2003, participants' most common associations with "global warming" were melting ice and rising temperatures, following by ecological impacts, ozone depletion, alarmist messages, and flooding from rivers or sea level rise (Leiserowitz, 2006). In a 2007 survey, adult residents of Michigan and Pennsylvania who reported that they believed that global warming was happening cited the following factors as having at least some effect on that belief: recent years' warming temperatures in their area and declining polar ice and glaciers (Borick & Rabe, 2010).

These perceived impacts of climate change are similar to those reported by individuals who believed they had personally experienced them. For instance, in a 2010 survey in Michigan, respondents who believed they had personally experienced climate change described those effects as changes in seasons, weather, lake levels, animals and plants, or snowfall (Akerlof et al., 2013). Perceptions about climate change extend to specific extreme weather events: a majority of respondents in a 2012 survey of the US agreed that global warming had made the following events in the past year "worse": record high summer temperatures, unusually warm spring and winter, drought in the Midwest and Great Plains, and record forest fires (Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Howe, 2012a).

Perceptions of Extreme Temperature Events

No published studies to date were identified that examined how individuals' perceptions of extreme temperature events (hot or cold) were influenced by the actual occurrence of such events. Climate change is increasing both average temperatures and the frequency of unusually hot events (IPCC, 2014), so extremely high temperatures may be interpreted by the public as a signal that climate change is real, and thus increase their perceptions that they have experienced it. Conversely, extreme cold temperatures may seem counterintuitive to global "warming" and may cause individuals to interpret them as evidence against climate change, and decrease their perceptions of personal experience with climate change.

Some studies suggest that extreme temperature events can shape respondents' belief in climate change. One study found that respondents with unusually hot local temperatures for up to one year (above the 75^{th}, 90^{th}, and 95^{th} quantiles of normal) were more likely (based on an ordered probit regression) to think that the effects of global warming have already started (Deryugina, 2013). Furthermore, as the temperature threshold increased, the size of the effect on belief increased, suggesting that more extreme temperatures are more influential on perceptions (Deryugina, 2013). This influence was largely symmetrical: extremely cold temperatures *decreased* the likelihood that respondents believed that global warming had already started

(Deryugina, 2013). Another study found that survey respondents who had experienced heat waves (temperatures at least 10 degrees Fahrenheit above normal for seven or more days in a row) were more likely to (based on an ordered probit regression) believe that there is "solid evidence" that global warming is happening, compared to those who had experienced the same number of non-consecutive hot days (Egan & Mullin, 2012).

Perceptions of Severe Storm Events

Previous research examining the public's perception of their personal experiences with severe storms suggests that there is the potential for these perceptions to be accurate because such storms are very salient. A 2012 US survey found that perceptions of personal experience with hurricanes in the preceding year was significantly higher for respondents in areas that had experienced a hurricane during that time period compared to respondents who were not in the path of the hurricane (Howe et al., 2014). This is not surprising, as only one hurricane (Irene) occurred during the 1-year study period and affected much of the US East Coast (North Carolina through New England). Studies of social media support these survey findings that personal experience with superstorms is salient to the public. Twitter activity about Hurricane Sandy in 2012 was significantly negatively correlated with the user's distance to the path of Hurricane Sandy (Kryvasheyeu et al., 2015), meaning that those who were closer and thus personally experienced the Hurricane were discussing it more. Furthermore, around Hurricane Sandy there was a significant decrease in Tweets about climate change skepticism (An, Ganguly, Scyphers, & Dy, 2014) and an increase in "sad" sentiment about climate change on Twitter (Cody et al., 2015), suggesting that hurricanes on the East Coast are seen as a negative and emotionally charged impact of climate change.

One study suggests that perceptions of changes in hurricane incidence over time may be accurate. In a 2011 survey, US Gulf Coast residents' perceptions of whether the number of hurricanes was increasing, decreasing, or staying the same was significantly higher for respondents in counties with an increasing trend in annual hurricane frequency, as predicted using logistic regression (Shao & Goidel, 2016). This relationship was significant when perceptions were compared to actual 15- and 19-year hurricane trends, but not 10-year trends. The authors suggest that there were too few hurricanes during the 10-year time period (2002-2011) "to form any meaningful trends for the public to detect" (p. 13). This supports the theory that individuals find it difficult to accurately process infrequent weather events (Weber & Stern, 2011).

Perceptions of Flood Events

Flooding can be an indirect impact of climate change, caused by interactions between extreme precipitation, sea level rise, storm surges, and the vulnerability of human settlements in areas near streams, rivers, and coasts (IPCC, 2014). The abundance of other possible causes of flooding means that only some of the general public considers it a potential impact of climate change: in a 2003 survey of residents in a part of southern England with recent flooding, 21% identified flooding as a climate change impact, while others instead attributed flood events to local institutional causes, such as road and waterway maintenance (Whitmarsh, 2008). Additionally, it can be challenging for study authors to estimate individuals' actual flood experiences, as floods are very localized but are often recorded at the county or county zone level; this may explain why only two studies (Goebbert et al., 2012; Shao & Goidel, 2016) were identified that examine the influence of actual flooding on perceptions of such events.

There is mixed evidence for whether perceptions of personal experience with flooding are significantly related to actual events. A 2008-2011 survey of the general US public found that respondents' perception of changes in flood frequency over the past few years (rising, falling, or staying the same) was significantly correlated with recent soil moisture levels (the preceding 3 years) levels compared to a historical 30-year average; respondents in dryer areas reported that flood frequency had been decreasing (Goebbert et al., 2012). The authors used soil moisture as a proxy for flood incidence, reasoning that floods are more likely with higher-than-normal moisture levels, but this may be an imperfect indicator and therefore the results of this study should be interpreted with caution. A2011 study of residents in the Gulf Coast region found that actual flood frequency over the past 10, 15, or 19 years were not significant predictors of perceptions of whether the amount of flooding had changed or stay the same (Shao & Goidel, 2016). Since only these two studies were identified, it is unclear whether the public's flood perceptions are accurate, and is an area that would benefit from further research.

Perceptions of Drought Events

While climate change impacts on trends in drought vary geographically, there is predicted to be an increased drought frequency in some areas (IPCC, 2014). The US public also attributes drought impacts to climate change, as suggested by a 2012 survey finding that individuals reported that global warming had made US droughts worse over the past year (Leiserowitz et al., 2012a). Therefore, there is the possibility that drought may be involved in experiential processing of climate change.

There is evidence that actual drought levels may influence perceptions of personal experience with drought. A 2012 online survey of US adults found that those who reported having personally experienced drought over the past year were more likely to live in areas with high drought prevalence (over the preceding 15 months), namely the Southwest, Southern Plains, and Southeast US (Howe et al., 2014). In 2008-2011 US surveys, perceived changes of drought frequency in the past few years were significantly related to three-year drought level anomalies measured using the Palmer Drought Severity Index (Goebbert et al., 2012). In a 2010 survey of residents of Alger County, MI, 24% of those that reported experiencing weather anomalies described local lake levels as decreasing, which matched the actual trend in measured anomalies from mean high water levels of Lake Superior, which borders the respondents' county (Akerlof et al., 2013). While lake levels are a visible signal of water availability, they do not necessarily indicate a drought. However, during the study period there had recently been over a year with below-average lake levels (late 2006 through early 2008) (Akerlof et al., 2013), which could indicate potentially serious low water levels. Only one study found that perceptions of drought were not accurate: the actual number of droughts in the Gulf Coast Region over the previous 10, 15, or 19 years was not a significant predictor of residents' perceptions in 2011 of whether drought frequencies had been changing (Shao & Goidel, 2016).

Perceptions of All Extreme Weather Events

As described in the above sections, many types of extreme weather events are increasing with climate change and linked in the minds of the public to climate change even when a single event occurs. As a result, some studies have examined the public's experiential processing of overall extreme weather but using an index containing multiple types of extreme weather. Four studies were identified that compared perceptions of extreme or unusual weather to actual occurrence of "storm events", using data from the NOAA Storm Events Database (Akerlof et al., 2013; Cutler, 2015; Shao, 2016; Shao & Goidel, 2016). The storm events in this database include hot and cold temperatures, precipitation, wind, storms, flooding, drought, fog, tides, and tornadoes (NOAA NWS, 2007). However, not all of these weather events may be associated with climate change, and some may actually be decreasing with climate change in many areas (e.g., cold temperatures and winter precipitation). As a result, using an index that is merely a sum of these various measures may not consistently represent experience that individuals would consider as evidence for or against the reality of climate change. One study qualitatively assessed overall respondents' observations that there had been general changes in weather, including warmer temperatures, decreased rainfall, and increased storms and "extreme weather" (Akerlof et al., 2013). Respondents' perceptions of increasing unusual weather, including some reported storm impacts, matched the recent increase in storm events over the past 16 years (Akerlof et al., 2013).

Two studies support the theory that individuals experientially process extreme weather in a way that heavily weights recent events and neglects older events. A 2007 survey of US residents found that respondents were more likely to report experiencing stranger-than-usual weather over the past few years as the total number of extreme events they had occurring in their county increased (Shao, 2016). This relationship was not significant, however, when the actual number of extreme events was measured as an anomaly, compared to a 30-year historical baseline (1971-2000) (Shao, 2016). Similarly, a 2011 study in the US Gulf Coast region found that trends in extreme weather events over the past 10, 15, or 19 years were not significant predictors of how likely respondents were to consider the weather being different from normal (Shao & Goidel, 2016).

One additional study compared storm event frequency and damage as predictors of individuals' perceptions of extreme weather events. Surveys from 2009 to 2011 in rural counties across the US found that individuals were more likely to report that extreme weather-related events had affected their families or communities over the past five years if they had higher amounts of property damage from storm events increased over that time period (Cutler, 2015). However, perceptions of extreme weather effects were not significantly related to the frequency of storm events alone (Cutler, 2015). This suggests that the salience of extreme events are not tied to their meteorological rarity, but also to their negative impacts, which would support the risk-as-feelings hypothesis described earlier (Loewenstein et al., 2001).

Research Questions

Previous research suggests that there is the potential for individuals to experientially process extreme weather events: individuals who experienced extreme events were more likely in some cases to think that those events were increasing in frequency or that the weather was become more unusual. This study assesses whether the public experientially processes climate change through extreme weather, by evaluating whether overall perceptions of climate change and extreme weather events are influenced by recent extreme weather events. Recent weather events (over a few years preceding the survey) are used because prospect theory suggests that events that have just happened will be seen as more certain than events that occurred further in the past and are uncertain to happen in the future. Research questions also account for motivated reasoning, which could limit experiential processing by shaping perceptions of climate change and extreme weather events based on pre-existing views, such as the belief that climate change is happening.

Research Question 1: Do recent extreme weather events influence perceptions of overall personal experience with climate change?

Two types of extreme weather events will be evaluated, based on their relevance to the study area (see Methods section) and potential link to climate change.

- **Hypothesis 1.1**: Recent winter weather and extreme cold events will predict perceptions of personal experience with climate change, controlling for motivated reasoning. Winter and spring are the seasons in which temperatures in the US are warming the most (Melillo et al., 2014), so extreme events during this season are likely most salient to the study population. The public associates climate change with decreases in general winter conditions, including: warming temperatures, melting glaciers or sea ice, and decreases in snow[4] (Akerlof et al., 2013; Borick & Rabe, 2010; Leiserowitz, 2006; Leiserowitz et al., 2012b). As a result, perceptions of personal experience are predicted to be higher for individuals with fewer winter weather and extreme cold events.
- **Hypothesis 1.2**: Recent flood events will predict perceptions of personal experience with climate change, controlling for motivated reasoning. Floods are predicted to increase in the northeast US as a result of climate change, as a result of more frequency heavy precipitation events and sea level rise (Melillo et al., 2014). As some of the public associates severe storms and flooding with climate change (see Literature Review), there is the potential for these extreme events to increase individuals' perceptions of climate change impacts.

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[4] Winter precipitation is actually predicted to increase in the northeastern US as a result of climate change (Melillo et al., 2014), which differs from general public perceptions that winter and cold conditions will decrease with warming temperatures.

Research Question 2: What aspect of recent extreme weather events influence perceptions of overall personal experience with climate change?

Extreme weather events vary in the magnitude of their impacts (e.g., number of individuals affected, injuries or casualties inflicted, or damages caused). As a result, it is helpful to examine both the number of extreme events while concurrently examining impacts as predictors of individuals' perceptions of personal experience. Only one previous study was identified that compared extreme weather events as measured by frequency to property damage inflicted; this study will also assess whether experiential processing of extreme weather events is more influenced by an event happening (the number of extreme events) or by its magnitude (damage incurred).

- **Hypothesis 2**: Impacts resulting from extreme weather events will more strongly predict perceptions of personal experience than will number of events, controlling for motivated reasoning.

Methods

This research assesses recent extreme weather events and perceptions of climate change impacts in New York State (NYS). This study area was chosen because NYS provides a sample with variation in climate, topographical features and water bodies, economic sectors, and population socio-demographics (Rosenzweig et al., 2011). Climate change is projected to cause varying impacts across the seven climate regions in NYS (climate regions are described in Figure 0.1).

Some climate regions are at risk for decreasing winter recreation conditions (Tug Hill Plateau, Adirondack Mountains, Catskill Mountains and West Hudson River Valley regions).

Others face agricultural risks from heat and drought (Great Lakes Plain, Southern Tier, Adirondack Mountains, East Hudson and Mohawk River Valleys, Catskill Mountains and West Hudson River Valley regions). Flooding may increase in some regions (New York City and Long Island, East Hudson and Mohawk River Valleys, Southern Tier regions) while water shortages could affect drinking water or hydropower resources in others (Tug Hill Plateau, Catskill Mountains and West Hudson River Valley regions). More densely populated regions are at risk from increasing heat-related illness and energy demands (New York City and Long Island region) (Rosenzweig et al., 2011).

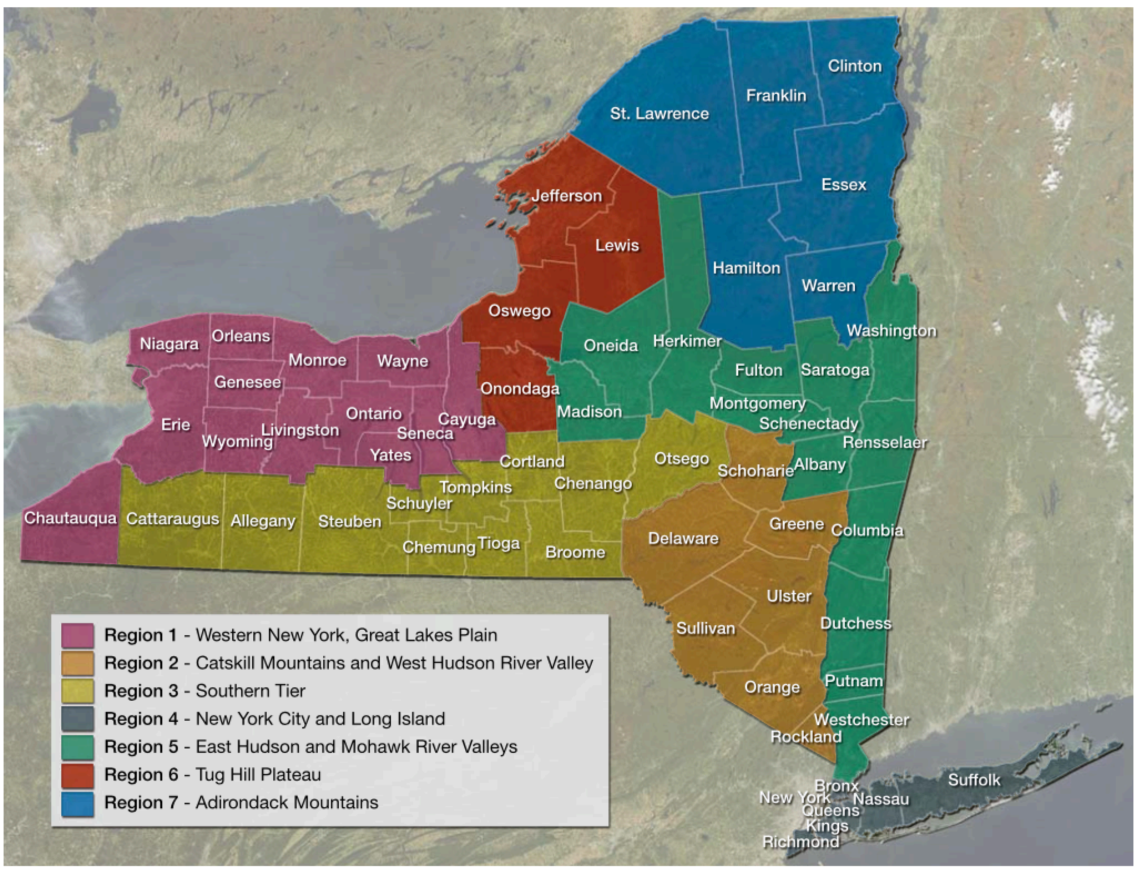

Figure 0.1 New York State climate regions described by the New York State Energy Research and Development Authority. Climate regions are marked by color, while county boundaries and names are labeled in white text and border. Figure from Rosenzweig et al. (2011).

Survey Methodology

Individuals' perceptions of their personal experience with extreme weather or climate change was measured through a telephone survey of NYS adults from January to March 2014, the 2014 Empire State Poll (ESP). The sample was evenly split between downstate (9 counties around New York City and Long Island) and upstate (the remaining 52 counties), with a final sample size of 800 total respondents. Administered by the Survey Research Institute at Cornell University, the ESP was a dual-frame random digit dial telephone (land-line and cellular) survey administered in both English and Spanish, using a sample acquired from the Marketing Systems Group that excluded known business, disconnected, and non-household telephone numbers. All other listed NYS telephone numbers had an equal chance of being included in the survey, and for each telephone number there was a random selection of household member based on most recent birthday, of those that were an adult and NYS resident. Population-based sample weights based on 2009-2011 US Census data were used so that the study sample is representative of NYS residents (Xian & Meyers, 2014). The response rate was 21% (n = 800) and the cooperation rate was 66%, which are both comparable to characteristics of other NYS surveys in recent years (Xian & Meyers, 2014).

Study Measures

Perceptions of personal experience, the dependent variable, were measured as respondents' agreement with the statement: "I have personally experienced the effects of extreme weather or climate change (on a 5-point scale from "strongly disagree" = 1 to "strongly agree" = 5). Since belief in climate change has been shown to strongly influence the public's perception of their personal experience with climate change (e.g., Cutler, 2015; Myers et al., 2013), this was used as a control variable in analyses. Climate change belief was measured using the question, “Do you believe that climate change is happening?” Responses were measured as yes (coded as 1), no (coded as 0), or don’t know (excluded from analyses).

Extreme Weather Events

Extreme weather events (the independent variables) were collected for a recent time period preceding the implementation of the ESP so that they would still be salient in respondents’ minds. Using a time period of at least one year would capture extreme events across all seasons, but extreme events are unusual enough that examining only one preceding year might miss some recent but salient events. Previous studies evaluated the incidence of extreme weather events for one, three, or ten or more years prior to measures of perceived personal experience with those impacts (see Literature Review). This study examines extreme weather events during the three calendar years (2011-2013) before the survey was administered, as it includes the occurrence of several salient storms in NYS (described further below).

Extreme weather events were obtained from the NOAA Storm Events Database of the National Weather Service. All events in this database meet the following criteria as defined by NOAA: significant weather phenomena having sufficient intensity to cause loss of life, injuries, significant property damage, or disruption to commerce; rare or unusual weather phenomena that general media attention; and other significant meteorological phenomena related to another event (NOAA NWS, 2007). This study considered two types of extreme weather events that were likely to be salient to NYS respondents at the time of the study: 1) winter weather and extreme cold events and 2) flood events. Table 0.1 describes the NOAA Storm Events Database phenomena that are included in each of these types. The extreme weather phenomena within each type do not overlap, as each has very specific definitions and criteria; for example, the *cold/wind chill* category is defined as low temperatures below local advisory criteria or impacts resulting from low temperatures, while *extreme cold/wind chill* is reserved for temperatures below a more severe advisory criteria. The level of analysis for NOAA Storm Events Database is county or county zone. All county zone locations were translated into their relevant county and duplicate events within a county were reduced to one event: for example, if a single flood (identified by "episode ID" in the NOAA Storm Events Database) affected both the northeastern and southern zones of a county, it would only be counted once for that county.

Table 0.1 Types of extreme weather events used in this study. Categories created from specific extreme weather phenomena identified in the NOAA Storm Events Database.

Categories	Definitions of extreme weather phenomena (NOAA NWS, 2007)
Winter weather and cold events	• **Blizzard**: winter storm with winds and snow reducing visibility • **Heavy snow**: snow accumulation above warning criteria • **Lake-effect snow**: snow accumulation above warning criteria (near Great Lakes) • **Ice storm**: accretion above warning criteria • **Winter weather**: winter weather event with damage/impacts, but does not meet warning criteria for any hazards • **Winter storm**: winter weather event with 2+ significant hazards and exceeds warning criteria for at 1+ hazard • **Cold/wind chill**: low temperatures below advisory criteria or with impacts • **Extreme cold/wind chill**: low temperatures below more extreme advisory criteria • **Frost/freeze**: frosts causing human or economic impact or agricultural damage
Flood events	• **Coastal floods**: ocean coasts • **Lakeshore floods**: lake coasts • **Storm surge**: ocean coasts, associated with storms • **Flash floods**: inland, fast onset • **Floods**: inland, not captured by other categories • **Seiche**: standing wave in an enclosed lake that causes flooding or damage • **High Surf**: large waves breaking on or near shore

Two different measurements of extreme weather events were assessed in this study: the number of extreme events and the impact resulting from extreme events over the study period. Entries for extreme weather phenomena in the NOAA Storm Events Database also include resulting impacts, including injuries, fatalities, property damage, and crop damage. Property damage was selected for this analysis because it was a relatively common impact of extreme weather and likely to affect the general public; this measure includes damage to private property and public infrastructure and facilities. Because property damage values were highly skewed as a result of a couple counties having order-of-magnitude higher damage than all other counties, property damage measures were log10-transformed. Because the dataset contained zeroes, which prohibited log-transformation, a constant (1) was added to all values prior to transformation.

Two additional types of extreme weather not present in the NOAA Storm Events Database during the time period of this study, drought and hurricanes (or tropical storms), and were thus not included. No droughts occurred during the study time period that were extreme enough (of "severe" drought level or higher in NYS) to be included in the NOAA Storm Events Database. During the study period, several hurricanes impacted NYS and garnered public and media attention. However, upon landfall in NYS, only Hurricane Irene in 2011 was still classified as a "Tropical Storm" in the NOAA Storm Events Database because it was the only storm with a Hurricane or Tropical Storm warning issued. Even though the named hurricanes and tropical storm events are not included in this study, the impacts of Hurricane Irene and the other two named storms of interest (Lee in 2011 and Sandy in 2012, for which no storm warnings were issued) are captured in the NOAA Storm Events Database as widespread flood events.

Data Analysis

To visualize the distribution of extreme weather impacts across NYS, maps were created in QGIS, an open-source Geographic Information System application. All descriptive statistics and analyses were performed in R. ESP respondents' perceptions of personal experience with extreme weather or climate change were compared to the extreme weather events in the county in which they resided.

First, a Spearman correlation was used to assess the strength of the relationship between perceptions of personal experience, belief in climate change, and all types extreme weather events. Next, multiple linear regressions were used to examine whether climate change belief and extreme weather events and property damage were significant predictors of perceptions of personal experience. The dependent variable (respondents' agreement that they had personally experience the effects of climate change or extreme weather) was treated as a continuous 5-point variable. Regression analyses included sample weights so that results are representative of NYS residents.

Results

Descriptive Results

The majority of ESP respondents (69%) agreed or strongly agreed that they had personally experienced the effects of extreme weather or climate change (Table 0.2). Only 13% of respondents were neutral, and 18% disagreed or strongly disagreed with the question statement. Most respondents (81%) believed that climate change is happening, and very few responded that they did not know whether it was happening or not (4%) and so were excluded from analyses.

Table 0.2. Descriptive results from the 2014 Empire State Poll.

Survey question	Coding	Response options	Respondents (n)
Personal Experience	1	Strongly disagree	5% (40)
How much do you agree or disagree with the	2	Disagree	13% (103)
following statement: I have personally	3	Neutral	13% (103)
experienced the effects of extreme weather	4	Agree	30% (241)
or climate change	5	Strongly agree	39% (313)
Belief	0	No	15% (121)
Do you believe that climate change is	1	Yes	81% (648)
happening?	-	Do not know	4% (31)

Winter weather events and flood events occurred in most counties from 2011 to 2013 (Table 0.3) but differed in frequency and spatial distribution (for overview of NYS climate regions, see Figure 0.1). At least three winter weather and extreme cold events occurred in all counties during the study period, with the highest frequency in the East Hudson River and Mohawk River Valleys, Adirondack Mountains, and Great Lakes Plain regions. Fewer than half of all counties had recorded property damage from winter weather and extreme cold events, and it was largely confined to the northern Adirondack Mountains and the Great Lakes Region, plus a single county with the highest amount of damages on Long Island. Flood events occurred in most counties during the study period. The most frequent events were largely concentrated in New York City and Long Island, Catskill Mountains and West Hudson River Valley, East Hudson and Mohawk River Valley, and Adirondack Mountains. The highest damages from flood events were generally situated in the Adirondack Mountains, Catskill Mountains and West Hudson River Valley, and Southern Tier regions.

Table 0.3 Extreme weather events and property damage in the counties of 2014 Empire State Poll respondents during 2011 - 2013. Original data are from the NOAA Storm Events Database.

Types of Extreme Weather	Number of events		Property damage ($1,000)	
	Range	Mean	Range	Mean
Winter weather and extreme cold events	3 - 42	12.53	0 - 32,000	1,850
Flood events	0 - 22	9.2	0 - 507,340	8,020

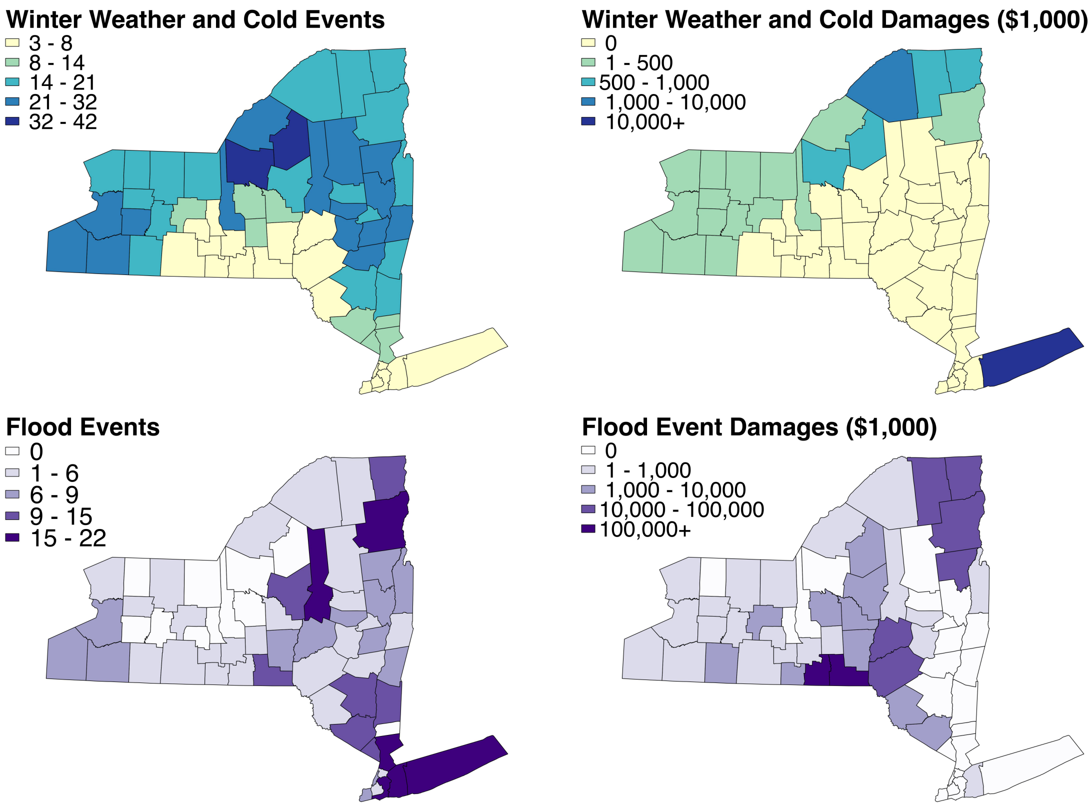

Figure 0.2 The number of extreme weather events and resulting damage that occurred in each New York State county (2011-2013). Original data are from the NOAA Storm Events Database.

Motivated Reasoning

Results suggest that motivated reasoning shapes respondents' perceptions of personal experience with the effects of extreme weather or climate change, as perceptions differed between climate change believers and deniers. Of respondents who did not believe in climate change, 41% agreed or strongly agreed that they had personally experienced the effects of extreme weather or climate, while 43% of climate change deniers disagreed or strongly disagreed with this statement (Table 0.3). The majority of respondents who believed in climate change (76%) agreed or strongly agreed that they had personally experienced extreme weather or climate change.

Table 0.4 2014 Empire State Poll respondents' perceptions of personal experience with the effects of extreme weather or climate change, as a percentage (number) of respondents who believe or do not believe that climate change is happening.

Perceptions of Personal Experience	Climate Change Belief	
	Yes (n = 645)	No (n = 118)
Strongly disagree	2% (20)	16% (19)
Disagree	10% (64)	27% (32)
Neutral	11% (72)	18% (21)
Agree	31% (201)	25% (30)
Strongly agree	45% (291)	16% (19)

Furthermore, climate change belief was significantly correlated with (Table 0.5) and a significant predictor of (Table 0.6) perceptions of personal experience. Climate change belief was positively related to perceptions of personal experience, meaning that believing in climate change increases individuals' perception that they have experienced the effects of climate change or extreme weather. In the regression model using only belief as a predictor variable (Table 0.6, Model 1), the average respondent who did not believe in climate change was predicted to neither agree nor disagree with the statement that they had personally experienced the effects of extreme weather or climate change (intercept = 3.10). In comparison, respondents who did believe in climate change on average agreed that they had personally experienced its effects, which was about a 1-point increase in the dependent variable (beta coefficient = 0.98). Climate change belief explained about 8% of the variance in respondents' perceptions of personal experience (adjusted R^2). The regression coefficient for climate change belief did not change much when weather measures were added as additional predictor variables.

Research Question 1: Do recent extreme weather events influence perceptions of overall personal experience with climate change?

Hypothesis 1.1 was partially supported, as the number of winter weather and extreme cold events was significantly correlated with perceptions of personal experience (Table 0.5) and a significant predictor of perceptions of personal experiences (Table 0.6, Model 2). The relationship was negative, meaning that respondents in areas with fewer winter weather and cold events from 2011 to 2013 agreed more that they had experience the effects of extreme weather or climate change. Figure 0.3a shows that while there was a wide range in the number of winter weather and extreme cold events for respondents in all categories of perceptions of personal experience, respondents with few winter weather and cold events tended to agree or strongly agree while respondents with many winter events were spread out between the response groups. This effect was similar for both respondents who believed that climate change is happening as well as those that did not. Property damage resulting from winter weather and extreme cold events over the study period was neither significantly correlated with (Table 0.5) nor a significant predictor of perceptions of personal experience (Table 0.6, Model 3).

Hypothesis 1.2 was not supported. Property damage from flood events was significantly correlated with perceptions of personal experience (Table 0.5) and a significant predictor of perceptions of personal experiences (Table 0.6, Model 5); however, this relationship was negative, suggesting that individuals in areas with less flood damage agreed more that they had experienced the effects of climate change or extreme weather. Flood events were hypothesized to be positively related to perceptions of personal experience, as floods may increase in NYS with climate change and some of the public associates increased flooding with climate change. Figure 0.3b shows that county flood damages for most respondents were zero or from $8,000 to $60,000,000 (about 3 to 8 on the log-transformed scale), with the highest amounts around $500,000,000 (about 8.75 on the log-transformed scale). The number of flood events over the study period was neither significantly correlated with (Table 0.5) nor a significant predictor of perceptions of personal experience (Table 0.6, Model 4).

Extreme weather events did not influence respondents' perceptions of personal experience with extreme weather or climate change as much as climate change belief did. Belief in climate change was the predictor most strongly correlated with perceptions of personal experience (r = 0.29), meaning that motivated reasoning has a larger influence than the recent extreme weather measures examined in this study (Table 0.5). Furthermore, climate change belief was the predictor with the largest standardized beta coefficient, even when extreme weather predictor variables were included in multiple regression models, and explained the most variance in perceptions of personal experience (Table 0.6).

Research Question 2: What aspect of recent extreme weather events influence perceptions of overall personal experience with climate change?

Hypothesis 2 was not supported. Property damage (a measure of extreme weather impacts) due to recent winter weather and cold events was not a significant predictor of respondents' perceptions of personal experience, but the number of recent winter weather and cold events was a significant predictor. While property damage from flood events was a significant predictor of respondents' perceptions of personal experience, this relationship was negative, suggesting that individuals do not see flooding as an example of climate change impacts in NYS. Taken together, these results do not support the hypothesis that the impact and magnitude of extreme weather – as opposed to the frequency – are what influences perceptions of personal experience.

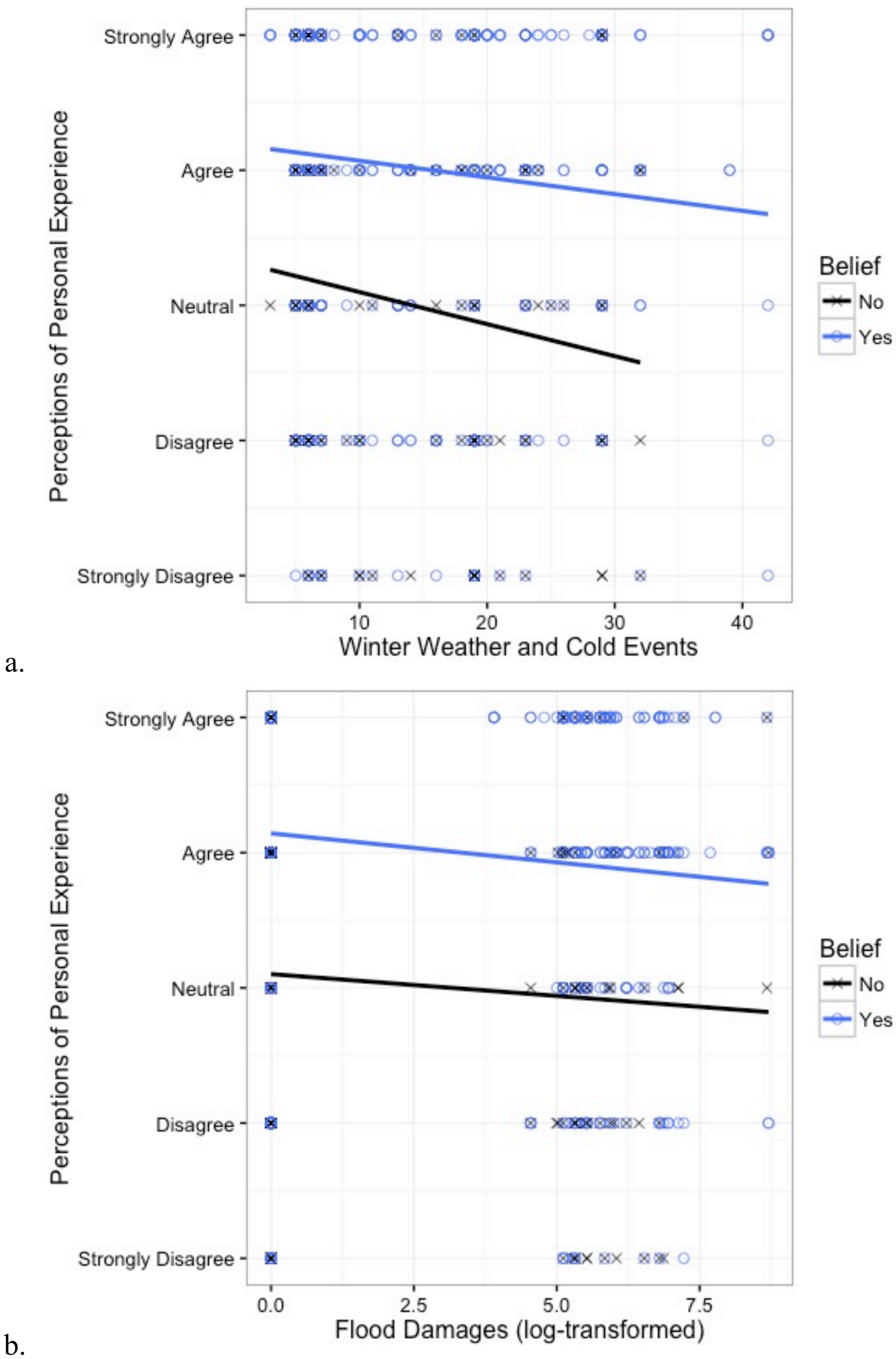

Figure 0.3 Respondents' agreement that they had experienced the effects of extreme weather or climate change as a function of the number of winter weather and extreme cold events (a) and flood damages (b) in their county from 2011 to 2013. Blue circles represent respondents who believe in climate change, while black Xs represent respondents who do not. Symbols are partly transparent, so that darker areas indicate a greater number of respondents with the same extreme weather measures and perceptions of personal experience.

Table 0.5 Correlation matrix between 2014 Empire State Poll respondents' perceptions of personal experience, climate change belief, and extreme weather events and damages (log-transformed) in respondents' county. Data are presented as the Spearman correlation coefficient. N = 763 for correlations including climate change belief; n = 793 for all others.

	Personal experience	Climate change belief	Winter weather and cold events	Winter weather and cold damages	Flood events
Climate change belief	0.29*				
Winter weather and cold events	-0.13*	-0.08*			
Winter weather and cold damages	-0.06	-0.09*	0.41*		
Flood events	0.03	0.02	-0.03	-0.08*	
Flood damages	-0.15*	-0.09*	0.35*	0.29*	-0.10*

*p < 0.05

Table 0.6 Regression models predicting perceptions of personal experience based on climate change belief and extreme weather events and damage (log-transformed) in respondents' county. Data presented as unstandardized *B* coefficients (standard error) and standardized *β* coefficients.

	Model 1 Belief		Model 2 Winter weather and cold events		Model 3 Winter weather and cold damages		Model 4 Flood events		Model 5 Flood damages	
	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β	B (SE)	β
Intercept	3.10** (0.11)	0	3.29** (0.13)	0	3.12** (0.11)	0	3.04** (0.12)	0	3.21** (0.12)	0
Belief	0.98** (0.12)	0.29	0.95** (0.12)	0.28	0.97** (0.12)	0.29	0.98** (0.12)	0.29	0.94** (0.12)	0.28
Winter weather and cold events			-0.02* (0.01)	-0.11						
Winter weather and cold damages					-0.01 (0.01)	-0.03				
Flood events							0.01 (0.01)	0.03		
Flood damages									-0.04* (0.01)	-0.10
Adjusted R^2	0.083		0.092		0.082		0.082		0.092	
p-value	<0.001		<0.001		<0.001		<0.001		<0.001	
df	761		760		760		760		760	

*p < 0.05, **p < 0.001

Discussion and Future Research

Experiential Processing of Weather and Climate Change

Results from this study suggest that extreme weather events may influence the public's perceptions of personal experience with overall weather and climate change, but this depends on the type of weather. This study found that individuals in areas with relatively few winter weather and extreme cold events agreed more that they had experienced the effects of extreme weather and climate change. One of the most well-known impacts of climate change is rising temperatures (Borick & Rabe, 2010; Leiserowitz, 2006; Leiserowitz et al., 2012a), with the fastest warming in the US occurring during the winter and spring seasons and the number of extreme cold events decreasing (Melillo et al., 2014). The public often associates warming temperatures with melting ice or decreased snowfall (Akerlof et al., 2013; Borick & Rabe, 2010; Leiserowitz, 2006), even though winter and spring precipitation is predicted to increase in the northeast (Melillo et al., 2014). The public perception that climate change is causing less winter weather (including cold temperatures and precipitation) suggests that such events have the potential to be involved in experiential processing of climate change.

Additionally, the survey used in this study was administered during the winter and spring, so cold temperatures and winter precipitation will be recent in respondents' minds; according to prospect theory, these recent and certain events will be especially salient to experiential processing. The salience of winter events in this study matches findings by other researchers that winter temperatures were generally related to perceptions of changes in temperature (Hamilton & Keim, 2009; Howe & Leiserowitz, 2013; McCright et al., 2014). Furthermore, cold temperatures were potentially very salient at the time of the study: during the survey administration, an usually cold front – caused by displaced polar air potentially due to decreased arctic ice as a result of climate change (Zhang, Tian, Chipperfield, Xie, & Huang, 2016) – affected much of the northeast US and was covered widely by the media (Sosnowski, 2014).

On the other hand, flood events did not increase respondents' perceptions of personal experience with extreme weather or climate change. Flood events were hypothesized to influence experiential processing of climate change because they are predicted to become more frequent in the northeast US (Melillo et al., 2014) and some of the public does consider both inland and coastal flooding, as a result of heavy precipitation and sea level rise, to be climate change impacts (Leiserowitz, 2006; Whitmarsh, 2008). Furthermore, during the study period several hurricanes made landfall in the northeast and were widely salient on social media, especially by respondents personally affected, and mentioned as being caused by climate change (An et al., 2014; Cody et al., 2015; Kryvasheyeu et al., 2015). Impacts from these storms included flooding (Melillo et al., 2014), and the NOAA Storm Events Database included flood events that were noted as being a result of these storms. The risks as feelings hypothesis proposes that emotional and publicized events are very influential to experiential processing (Loewenstein et al., 2001), which would fit such storm and flood events that are widely documented by social media and the news media.

The finding that more frequent flood events did not increase respondents' perceptions of personal experience may be due to more general challenges facing studies attempting to assess how extreme weather events influence experiential processing. It is not possible for large studies to quantify exactly how many extreme weather events individuals personally experience. While extreme events are widely publicized, their effects can still be very localized (such as inland flooding just around rivers) so aggregate measures at a larger scale (such as county, used in this study) do not reflect every individual. Extreme events may still be salient outside of their direct impact zone, as those that live nearby may hear about it through the news or on social media, and may work or have acquaintances in affected areas, but these indirect impacts may influence their perceptions differently than direct personal experience. Furthermore, Whitmarsh (2008) found that while some members of the public attribute flooding increases to climate change, a larger proportion reported that flood incidence depends on local institutional maintenance of roads and waterways, which highlights how climate change impacts, and extreme weather events in general, interact with existing vulnerabilities. In addition, the rarity of extreme weather events (leading to a very few specific events impacting a few individuals at any one time) increases the volatility of experiential processing of extreme weather and climate change. As a result, the influence on perceptions of extreme weather events on perceptions of personal experience may be measurable only directly following an event.

Motivated Reasoning

Pre-existing beliefs had a much stronger influence on perceptions of personal experience than did actual extreme weather events. This is not surprising, as it matches findings by other researchers (Cutler, 2015; Myers et al., 2013). Additionally, motivated reasoning is more influential in individuals with more strongly held beliefs that they feel the need to uphold. For example, belief in climate change and personal concern about global warming are greatly affected by political party identification and political ideology (with Democrats being more certain that it is happening and more concerned about it); this split increases with for individuals who think they understand a lot about the issues (as measured by education level or self-reported understanding) because they are more able to justify their view to themselves (for a review, see McCright, 2011). Future studies might examine if individuals who identify more strongly with a certain political party are more polarized in their perceptions of personal experience with climate change or weather compared to individuals who identify weakly with a party or as Independents.

Other Considerations

This study is limited in its measure of perceptions of personal experience. While the ESP asked respondents whether "have personally experienced the effects of *extreme weather or climate change*", they might have had different answers for whether they "have personally experienced the effects of *extreme weather*" compared to whether they "have personally experience the effects of *climate change*". For example, an individual who believed that climate change is happening but did not think they have actually experienced any extreme weather might still agree that they had, because they assumed that if climate change is real it could have affected them. Alternatively, a respondent who did not believe in climate change but did think they have experienced extreme weather might have disagreed because they did not want to say that they have experienced climate change. A 2015 national survey suggests that individuals' responses to these two questions are significantly correlated (Pearson $r = 0.26$, $n = 998$, $p < 0.001$) (unpublished data from the Cornell National Social Survey 2015), but that there is still a good deal of variation between those measures. Future studies should separate this into two questions to understand 1) which types of events influence individuals' perceptions of personal experience with extreme weather in general, and 2) which types of events individuals think are indicative of climate change.

Conclusion

The effect of climate change on local weather patterns and extreme events varies across the US and across seasons (Melillo et al., 2014). As a result, perceptions of personal experience climate change and weather have the potential to also differ by location, as well as by time. The results from this study suggest that in the northeast US, winter weather salient to how individuals experientially process climate change. As a result, communication and outreach on climate change impacts might be effective in this region by focusing on local warming temperatures. However, the linear relationship between winter weather events and perceptions of personal experience indicates that in areas where cold temperatures and winter precipitation are frequent, individuals may be less likely to think that they have personally experienced climate change.

Since individuals are most influenced by recent events (instead of uncertain future events) according to prospect theory, climate change engagement attempts could be according to the weather for maximum effect.

While this research focused on the general public, extreme weather events are also salient to professionals whose livelihoods are influenced by them. For example, some studies have examined farmer perceptions and actual incidences of drought and how these influence climate change beliefs and risk perceptions (Carlton et al., 2015; Diggs, 1991; Haden et al., 2012; Niles, Lubell, & Haden, 2013). Similarly, coastal cities sometimes increase adaptation efforts following severe events, such as Hoboken, New Jersey, following Hurricane Sandy in 2012 (Adhikari, Bellomi, & Mirescu, 2015). In the general public, perceptions of climate risks do not necessarily lead to more climate-friendly responses (Brügger et al., 2015), so perceptions and impacts may be more important to examine with decision-makers, either at the policy or community level.

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CONCLUSION

The influence of local weather on individuals' beliefs in, concerns about, and responses to climate change has been attributed to experiential processing, the way in which personal experiences can shape their understanding of a topic. This thesis assessed a small part of that: which types of weather affect the general public's perceptions of having personally experienced climate change or extreme weather. Results suggest that these perceptions are related to recent temperature conditions and extreme winter weather events for New York State (NYS) adults, providing support for the theory of experiential processing.

Approach

This thesis evaluated which types of weather influence experiential processing of climate change by comparing the influence of different types of weather on individuals' perceptions of personal experience with climate change or extreme weather (a possible impact of climate change). Two types of weather were addressed separately: recent temperature and precipitation conditions (Chapter 1) and extreme weather events (Chapter 2). Individuals' perceptions of personal experience were measured through a 2014 survey in NYS. Respondents' belief in climate change was included as a control variable in statistical models, as belief may cause individuals to interpret their experiences in a way that reinforce pre-existing views about whether climate change is happening or not.

Chapter 1 tested the potential for experiential processing to lead to variability in perceptions of weather and climate change by evaluating if perceptions were influenced by very short-term (daily or weekly) weather conditions, including temperature and precipitation levels. This study was unique in testing different measures of temperature and precipitation to see if individuals’ perceptions of experiences are based on absolute conditions (e.g., degrees Fahrenheit or inches of precipitation), or how those conditions compare to normal (conditions relative to a historical distribution, or “climate normal”). This study was able to estimate actual weather conditions in respondents’ local areas at the time of the study using a high-resolution gridded weather data from the Northeast Regional Climate Center. This avoided the precipitation data limitation that had affected previous studies (e.g., Hamilton & Stampone, 2013). Since respondents’ locations were only known at the county level, but there could be wide variation in weather conditions within counties (especially the large ones), county averages were weighted by census tract population numbers to more closely estimate the average weather experienced by individuals living in that county. Only one other study was identified that previously used population-weighted weather measures, in this case for national-level analyses (Howe et al., 2013).

Chapter 2 tested the potential for experiential processing to be swayed by extreme weather by testing if perceptions were influenced by different types of extreme weather events for three years prior to the survey. This chapter focused on relatively recent weather (over the past few years), since rare extreme events are likely to be either over- or under-weighted in perceptions of personal experience. This analysis assessed which extreme weather events are the most salient to the general public, as the possible impacts of climate change range from more frequent extremely hot temperatures and fewer cold temperatures to shifts in precipitation leading to drought and flooding. Additionally, this analysis evaluated how both the incidence of extreme weather events (measured as a frequency of events) and the impact magnitude (measured as property damage) influence perceptions.

Key Findings

Results in both chapters suggest that actual weather – either in the form of recent conditions or extreme events – can slightly influence perceptions of personal experience with climate change or extreme weather. In both chapters, the most influential types of weather were related to cold or winter weather. Individuals who lived in areas with higher absolute minimum temperatures the day of or the week before the survey (Chapter 1) and fewer winter weather and cold events during the three years preceding the survey (Chapter 2) were more likely to agree that they had experienced the effects of extreme weather or climate change. This supports findings from previous studies that winter temperatures tend to have the strongest effect on perceptions of personal experience with weather or climate change (Hamilton & Keim, 2009; Howe & Leiserowitz, 2013). Cold temperatures may have been salient in the previously mentioned studies as well as this thesis, as all the studies occurred in the winter or spring, the colder parts of the year.

Absolute maximum temperatures (Chapter 1) were also positively related to perceptions of personal experience, meaning that the respondents agreed more that they had personally experienced the effects of extreme weather or climate change as the maximum temperatures increased. The positive relationship between perceptions of personal experience with extreme weather or climate change and both absolute minimum and absolute maximum temperatures suggests that individuals' perceptions are shaped by both high and low temperatures. The influence of temperature on perceptions of personal experience with climate change or extreme weather is consistent with the fact that rising temperatures is the climate change impact most commonly mentioned by the general public (Leiserowitz, 2006).

The only two significant weather predictors in Chapter 1 were both absolute measures of weather conditions, suggesting that individuals perceive their experiences based on conditions at the moment, instead of based on conditions relative to normal. Perhaps a 30-year "normal" distribution – the shortest time period generally considered to represent climate conditions (Rosenzweig et al., 2011) – is too long for the general public to understand or perceive. The importance of absolute weather conditions to perceptions of personal experience with extreme weather or climate change can be explained by construal level theory and prospect theory, which both propose that experiential processing is very biased towards the present and recent past.

This research also provides support for the theory of motivated reasoning, which suggests that people reinforce previous ideas based on values and ideology when presented with new information (Chen et al., 1999; Kahan et al., 2012; Myers et al., 2013). In both chapters, pre-existing belief in climate change was a much stronger predictor of perceptions of personal experience with extreme weather or climate change than any type of weather. This can be attributed to the current ideological polarization around the topic of climate change (Dunlap et al., 2016).

Implications

This research contributes to the understanding of experiential processing theory by assessing which types of weather experiences influence perceptions. Many previous studies measured weather conditions or extreme weather impacts in the form of anomalies or trends (see Literature Review in Chapters 1 and 2), but this analysis and one other study (Shao, 2016) suggest that individuals instead respond to recent events only, without a longer-term context. These findings are consistent with theories about experiential processing (including construal level theory and prospect theory), which predicts that "close" (recent) experiences will be the most salient (Hertwig et al., 2012; Marx et al., 2007; Trope & Liberman, 2010). While the effect size of the relationships between perceptions of personal experience and certain types of extreme weather was small, this is to be expected because this study considers the influence conditions over a short time (one day, one week, or three years), but perceptions of climate change may be influenced be shaped by a lifetime of experiences as well as through a variety of social factors (e.g., motivated reasoning).

Public support for adaptation to climate change impacts may be influenced by individuals' experiences with these effects. For example, in a 2012 survey of New Jersey students where they were asked to rate two (fictional) politicians – one promoting ("for") climate action and the other against climate action – those impacted by Hurricane Sandy rated the "for" climate action politician more highly (Rudman, McLean, & Bunzl, 2013). The impacts of climate change differ across the US and interact with local conditions, suggesting that local governments may be the best positioned to adapt (Rosenzweig, 2011). In turn, local government action on climate change may be most successful when its constituents are engaged on the issue (Burby, 2003; Rootes, Zito, & Barry, 2012).

Some research has also suggested that individuals' personal experience with weather conditions or extreme events can also affect their belief in, concern about, and personal actions to combat climate change (Egan & Mullin, 2012; Hamilton & Stampone, 2013; Li et al., 2011). However, experiential processing not only provides new information about weather (and climate) states, but through the reveal of risks and impacts can instill fear, feelings of low self- efficacy, guilt and forced responsibility, which may instead prevent action on climate change (Brügger et al., 2015). Therefore, while personal experience with weather has sometimes been viewed as a way to promote climate concern and action (Lorenzoni & Pidgeon, 2006; A. Spence et al., 2012;

Weber, 2006), this may be appropriate to local situations where individuals have capacity to act and are less influenced by motivated reasoning. For example, a 2013 national survey found that support for resource policies – in this case shale gas – was most related to ideology when the resource in question was located far away, and instead more shaped by local conditions when respondents were close to the resource (Clarke et al., 2016).

Future Research

One of the limitations to this study was that it measured perceptions of personal experience with both climate change and extreme weather at the same time. For respondents who do not believe in climate change, the wording of the question may preclude them from saying that they had experienced it, even if they would have said they have experienced the effects of extreme weather. As a result, respondents may have interpreted or answered the question in varying ways. Additionally, separating perceptions of personal experience with *climate change* from perceptions of personal experience with *extreme weather* would allow researchers to examine whether individuals use experiential processing to update their perceptions of specific weather events or of climate change as a whole. Evidence suggests that perceptions of personal experience with climate change are significantly correlated to perceptions of personal experience with extreme weather (Pearson $r = 0.26$, $n = 998$, $p < 0.001$) (*unpublished data from the Cornell National Social Survey 2015*), but future studies should separate these two questions.

Factors shaping perceptions of climate change – both weather and social factors – may have spatial dependencies, so future studies should consider assessing the spatial relationship of the factors included. The sample population for this thesis was representative of NYS (because the 2014 ESP was intended for a state-level analysis), and as a result half of all respondents were located in the nine counties the downstate region, with many fewer respondents across the remaining 52 counties. However, this research was individual respondents and their location (county). The low sample size across counties precluded a statistical analysis to test for spatial dependencies and patterns, which could account for potential confounding factors that influence respondents with the same location but that are not captured by any of the independent variables tested. To carry out a statistical analysis of spatial dependence, future studies should representatively sample each population at the level of the unit of analysis.

To most accurately represent the weather conditions that individuals would likely encounter within a county, Chapter 1 utilized population-weighted average weather measures. This was to avoid situations in which the majority of the population within a county was located in an area with weather unlike that for the rest of the county, in which case a simple average would not capture the weather that people in the county were most likely to experience. This step was motivated by the concept of psychological geographic distance, and therefore tried to best estimate weather that would happen close to survey respondents. While preparing data for this study, all population-weighted averages were visually compared to simple averages, and did not differ greatly. However, it is difficult to measure the true impact of this adjustment to the weather data, as half of respondents were located in a few small (downstate) counties. However, it should be noted that calculating the population-weighted averages was the most time consuming step in the analysis, and therefore might be reserved for research using larger areas of analysis such as states or countries, as was done by Howe et al. (2013).

Conclusion

As climate change impacts continue to increase, they may continue to shape the general public's perceptions of the reality of climate change and the local risks that it poses. Results suggest that recent weather conditions and extreme events slightly shift these perceptions, although perceptions may be primarily driven by beliefs about climate change informed by values and ideologies. However, perceptions may also play a role in shifting these beliefs, and may lead to future action on mitigating and adapting to climate change, although this influence depends on many other factors. This thesis has contributed to understanding which types of weather may influence these perceptions, which can help policymakers understand which types of events are salient, as well as comprehending how perceptions of weather can be explained by the theory of experiential processing.

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APPENDIX A

SUMMARY OF LITERATURE REVIEWED

Table 0.1 Studies on the relationship between perceptions of weather or climate change and actual weather conditions

Study	Scope	Actual Temperature			Perceptions	Analysis & Results
		Units	Location	Duration		
Perceptions of Climate Change & Overall Weather						
Shao (2016)	US, Apr. 2007	Average seasonal temperatures for past 3 years compared to normal (1971-2000)	Participant county	3 years	Whether the weather in the past few years has followed its normal pattern or been stranger than usual	Logistic regression: NS
		Average seasonal precipitation for past 3 years compared to normal (1971-2000)				Logistic regression: NS
Hamilton and Keim (2009)	US (AL, CO, KS, KY, ME, MS, NH, OR, WA), 2007	38-year (1970-2007) trend in minimum and maximum winter temperatures (*other seasons tested with similar results, analyses not reported*)	Participant state	38 years	Whether global warming or climate change has had no effect, minor effects, or major effects on their family or community over the past 5 years	Regression: significant positive relationship (beta NR, $p = 0.026$) between weighted % of respondents reporting minor/major effects and winter temperature trend
Perceptions of Temperature						
Joireman et al. (2010)	North-western US, date NR	Temperature at time of interview	Interview facility	1 day (current)	Whether temperatures seem warmer now than in years before (7-point scale from "strongly disagree" to "strongly agree")	Correlation: significant positive relationship ($r = 0.24$, $p < 0.05$)
Li et al. (2011)	US, Feb. 2010	Average temperature on day of survey compared to historical average on that day (date range NR)	Participant zip code	1 day (current)	Whether local temperature that day was colder or warmer than usual for that time of year (5-point scale from "much colder" to "much warmer")	Correlation: significant positive relationship ($r = 0.49$, $p < 0.0001$)

Study	Scope	Actual Temperature			Perceptions	Analysis & Results
		Units	Location	Duration		
Perceptions of Temperature (cont.)						
Zaval et al. (2014)	US, date NR	Average temperature on day of survey compared to historical average on that day (for 15 years prior)	Participant zip code	1 day (current)	Whether the local temperature that day was colder or warmer than usual for that time of year (5-point scale: "much colder" to "much warmer")	Correlation: significant positive relationship ($r = 0.24$, $p < 0.01$)
				1 day (prior)	Whether the local temperature the previous day was colder or warmer than usual for that time of year (5-point scale: "much colder" to "much warmer")	Correlation: significant positive relationship ($r = 0.26$, $p < 0.01$)
				1 day (current)	The percentage of days over the past year that seemed warmer than usual for that time of year	Correlation: significant positive relationship ($r = 0.15$, $p < 0.01$)
McCright et al. (2014)	US (48 states), 2012	Winter temperature compared to historical average (1982-2011)	Participant State	1 season	How temperature in their local area have been this winter season compared to past winters (0 = "colder than usual or "about the same, 1 = "warmer than usual")	Logistic regression: significant positive relationship (unstandardized $b = 0.32$, $p < 0.05$)
Howe and Leiserowitz (2013)	US, 2011	Average monthly temperature anomaly compared to historical average (1971-2000)	Participant address	1 season	Has this winter in your local area been warmer, colder, or no different than normal?	Logistic regression: significant positive relationship (unstandardized $b = 0.24$, $p < 0.05$)
						ANOVA: higher for those reporting warmer winter, versus colder winter (mean difference = 0.26 °C, $p = 0.01$); NS versus normal winter
					Has this summer in your local area been warmer, colder, or no different than normal?	Logistic regression: significant positive relationship (unstandardized $b = 0.19$, $p < 0.05$)
						ANOVA: higher for those reporting warmer winter versus normal or colder summer (mean difference = 0.69 – 0.78 °C, $p <0.001$)

Study	Scope	Actual Temperature			Perceptions	Analysis & Results
		Units	Location	Duration		
Perceptions of Temperature (cont.)						
Howe et al. (2013)	89 countries, 2007-2008	12-month moving average of monthly temperatures compared to historical monthly average (for 1961-1990)	Country	1 year	Whether average annual temperatures in the local area have gotten warmer, colder, or not changed over the past 5 years ("gotten warmer" compared to "gotten colder" or not changed")	Multilevel binary logistic regression: significant positive relationship (b = 0.29, $p < 0.01$)
	46 countries, 2007-2008		Participant state (or equivalent unit)			Multilevel binary logistic regression: significant positive relationship (b = 0.48, $p < 0.001$)
Goebbert et al. (Goebbert et al., 2012)	US, 2008-2011	Average temperature for 3 years prior compared to average temperature (for 30 years prior)	Participant zip code	3 years	Whether average temperatures over the past few years have been rising, falling, or staying about the same	Ordered logistic regression: positive, marginally significant (logit model coefficient = 0.15, $p < 0.1$)
Shao and Goidel (2016)	US (TX, LA, MS, AL, FL), Jan. – Apr. 2011	Seasonal temperature trends over duration	Participant county	10 years	Whether temperatures have changed	Logit estimate: positive, significant (b = 0.086, $p < 0.05$) [summer only]
				15 years		Logit estimate: NS
				19 years		Logit estimate: NS
Perceptions of Precipitation						
Howe and Leiserowitz (2013)	US, 2011	Average monthly precipitation as a percent of compared to historical average (1971-2000)	Participant address	1 season	Has this winter in your local area brought more snow or rain, less snow or rain, or was it no different than normal?"	Logistic regression: significant positive relationship (unst. b = 1.08, $p < 0.001$)
						ANOVA: wetter for those reporting wetter winter versus those reporting the same or dryer winter (mean diff. = 18.4 – 22.2%, $p < 0.001$)
					Has this summer in your local area brought more snow or rain, less snow or rain, or was it no different than normal?"	Logistic regression: significant positive relationship (unst. b = 1.69, $p < 0.01$)
						ANOVA: wetter for respondents reporting wetter winter versus normal (mean diff. = 8.5%, $p < 0.02$); NS versus those reporting dryer summer

NR = not reported, NS = not significant

Table 0.2 Studies on the relationship between perceptions of weather and actual extreme weather events

Study	Scope	Actual weather			Perceived Weather	Analysis & Results
		Units	Location	Duration		
Perceptions of Climate Change and Overall Extreme Weather						
Shao (2016)	US, April 2007	Average annual # of extreme events (NOAA Storm Events Database) for past 3 years compared to normal (1971-2000)	Participant county	3 years	Whether the weather in the past few years has followed its normal pattern or been stranger than usual	Logistic regression: NS
		Total # of extreme events for past 3 years				Logistic regression: significant increase in % of respondents reporting stranger than usual weather ($B = 0.009$, $p < 0.001$)
Cutler (2015)	US (AK, FL, LA, ME, OR, WA) rural counties, 2009-2011	Frequency of storm events (NOAA Storm Events Database)	Participant county	5 years	Whether unusual or extreme weather-related events had no effect, minor effects, or major effects on their family or community over the past 5 years	Mixed-effects binary logistic regression: NS
		Property damage from storm events				Mixed-effects binary logistic regression: significant, positive relationship (odds ratio = 1.52, $p < 0.001$)
Akerlof et al. (2013)	US (Alger County, MI), Jun. – Sep. 2010	Trend in storm event frequency (NOAA Storm Events Database), based on yearly frequency compared to average for duration (1993-2009)	County	16 years	Changes in seasons, including (thunder) storms and extreme weather (open-ended responses to the ways participants had personally experienced global warming)	Qualitative analysis: perceived changes (increased storms) matches recent above-average storm incidence
Shao and Goidel (2016)	US (TX, LA, MS, AL, FL), Jan. – Apr. 2011	Trend in annual extreme weather events (NOAA Storm Events Database)	Participant county	10 years	Whether the weather was very different, somewhat different, or pretty much the same	Logistic regression: NS
				15 years		Logistic regression: NS
				19 years		Logistic regression: NS

Study	Scope	Actual weather			Perceived Weather	Analysis & Results
		Units	Location	Duration		
Perceptions of Storms						
Howe et al. (2014)	US, Apr. 2012	Hurricane incidence (only 1: Hurricane Irene)	Participant point location (*resolution NR*)	1+ year (15 months)	Whether they had personally experienced hurricanes in the past year	Chi-squared: respondents in hurricane-affected areas more likely to report personally experiencing a hurricane compared to the national baseline ($p < 0.01$)
Shao and Goidel (2016)	US (Gulf Coast region: TX, LA, MS, AL, FL), Jan. – Apr. 2011	Trend in yearly hurricane frequency	Participant county	10 years	Whether the number of hurricanes has changed	Logistic regression: NS
				15 years		Logistic regression: positive, significant ($b = 15.5, p < 0.001$)
				19 years		Logistic regression: positive, significant ($b = 40.6, p < 0.001$)
Perceptions of Flooding						
Goebbert et al. (Goebbert et al., 2012)	US, 2008-2011	Yearly average inverse of the Palmer Drought Severity Index compared to inverse average PSDI (for 30 years prior)	Participant zip code	3 years	Whether flood frequency over the past few years have been rising, falling, or staying about the same	Ordered logistic regression: positive, significant ($b = 0.18$, $p < 0.05$)
Shao and Goidel (2016)	US (TX, LA, MS, AL, FL), Jan. – Apr. 2011	Yearly flood frequency	Participant county	10 years	Whether the amount of flooding has changed	Logistic regression: NS
				15 years		Logistic regression: NS
				19 years		Logistic regression: NS

Study	Scope	Actual weather			Perceived Weather	Analysis & Results
		Units	Location	Duration		
Perceptions of Drought						
Howe et al. (2014)	US, Apr. 2012	15-month drought prevalence	Participant point location (*resolution NR*)	1 year	Whether they had personally experienced drought in the past year	Chi-squared: respondents in drought-affected areas more likely to report personally experiencing a drought compared to the national baseline ($p < 0.01$)
						Logistic regression: positive significant (beta coefficient = 0.05, SE = 0.01, $p < 0.001$)
Goebbert et al. (Goebbert et al., 2012)	US, 2008-2011	Palmer Drought Severity Index (PSDI) for 3 years prior compared to average PSDI (for 30 years prior)	Participant zip code	3 years	Whether drought frequency over the past few years have been rising, falling, or staying about the same	Logistic regression: positive, significant (logit model coefficient = -0.29, $p < 0.01$)
Akerlof et al. (2013)	US (Alger County, MI), Jun. – Sep. 2010	Lake Superior high water level compared to International Great Lakes Datum (2-3 measurements per year)	County	15 years	Changes in lake or water body levels (open-ended responses to the ways participants had personally experienced global warming)	Qualitative analysis: perceived changes (decrease water levels) matches recent below-average lake levels
Shao and Goidel (2016)	US (TX, LA, MS, AL, FL), Jan. – Apr. 2011	Yearly drought frequency	Participant county	10 years	Whether the number of droughts has changed	Logistic regression: NS
				15 years		Logistic regression: NS
				19 years		Logistic regression: NS

NR = not reported, NS = not significant

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APPENDIX B

SUPPLEMENTAL FIGURES

Chapter 1. The Influence of Recent Weather on Perceptions of Personal Experience with Climate Change and Extreme Weather in New York State

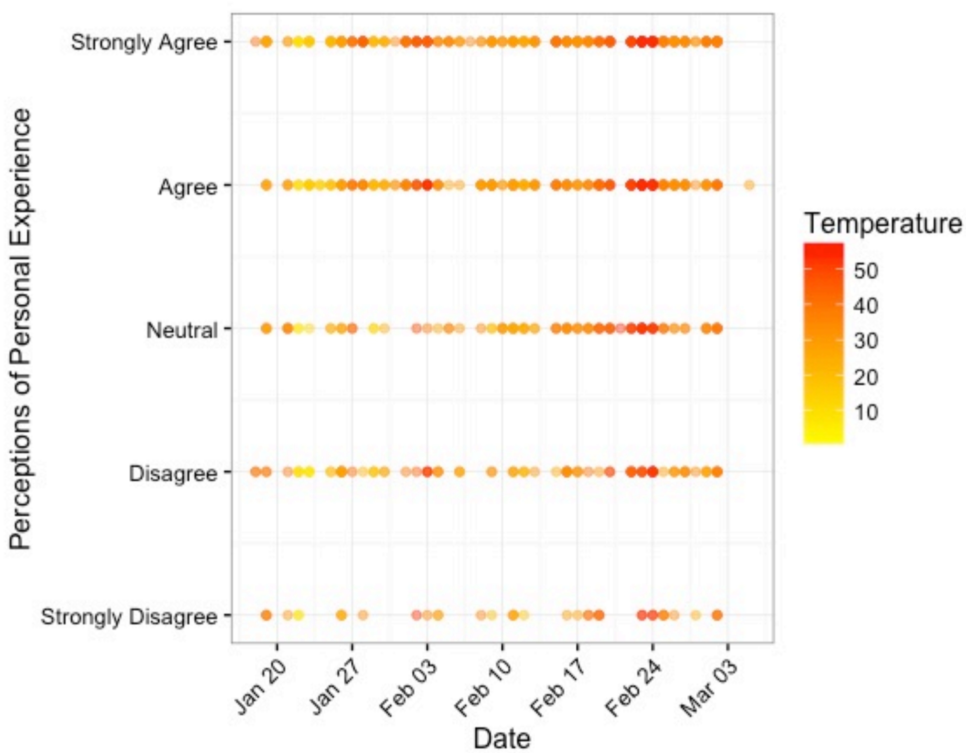

Figure 0.1 Respondents' agreement that they had experienced the effects of extreme weather or climate change as a function of the survey date (x-axis) and maximum temperature (°F) on the survey date in their county (colored shading). Each respondent is marked by a single filled circle; the circles are transparent, meaning areas of the graph that are darker had more respondents on that survey date with similar answers.

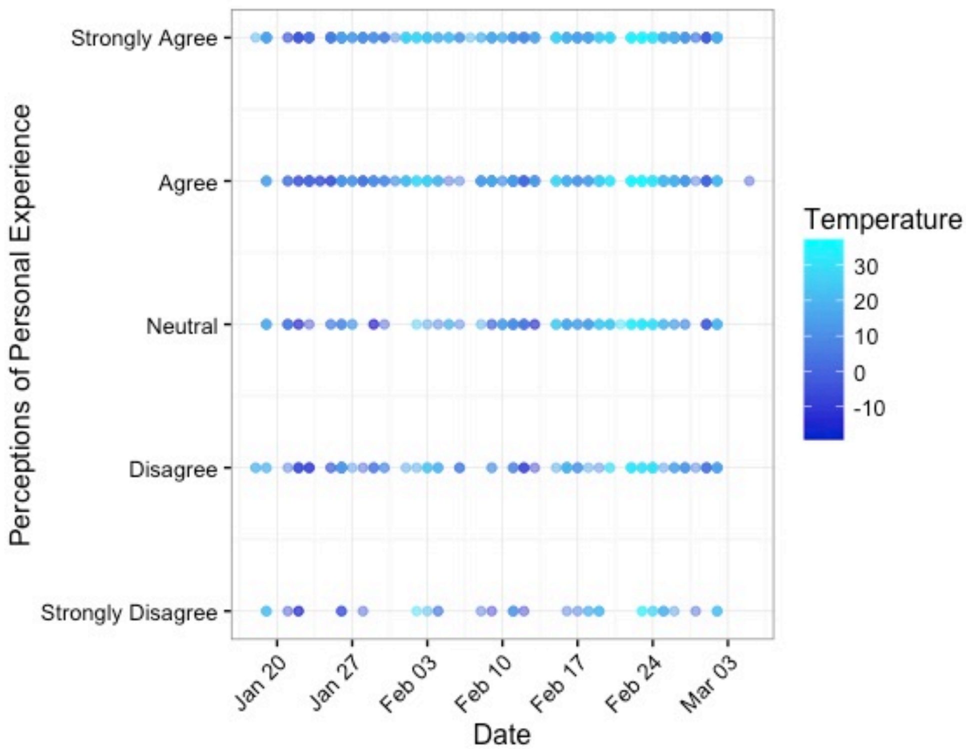

Figure 0.2 Respondents' agreement that they had experienced the effects of extreme weather or climate change as a function of the survey date (x-axis) and minimum temperature (°F) on the survey date in their county (colored shading). Each respondent is marked by a single filled circle; the circles are transparent, meaning areas of the graph that are darker had more respondents on that survey date with similar answers.

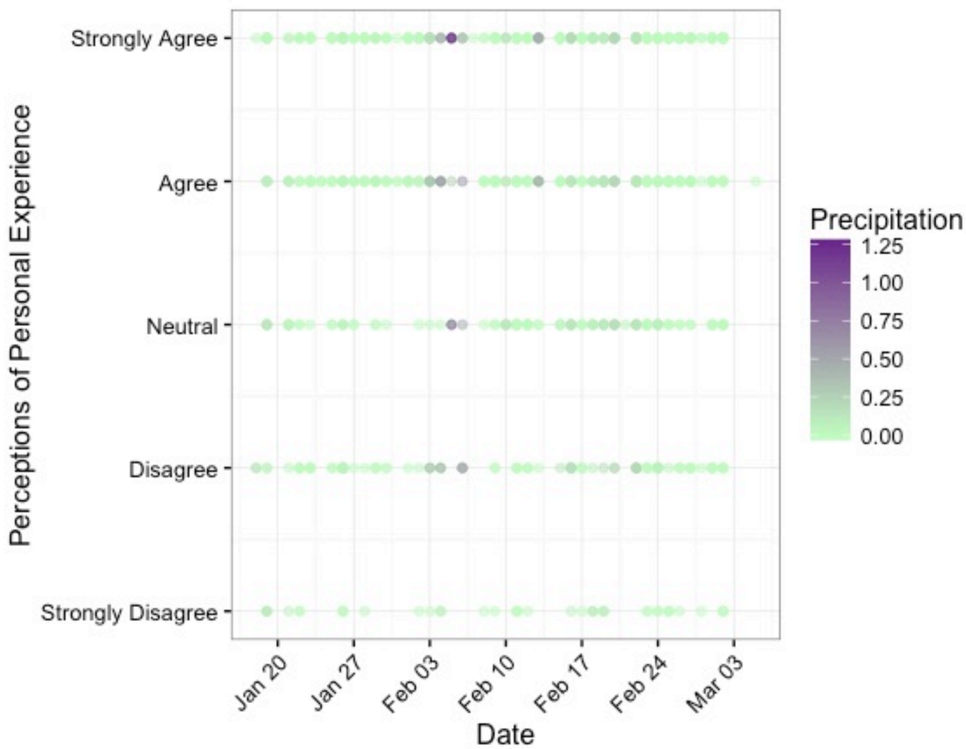

Figure 0.3 Respondents' agreement that they had experienced the effects of extreme weather or climate change as a function of the survey date (x-axis) and inches of precipitation on the survey date in their county (colored shading). Each respondent is marked by a single filled circle; the circles are transparent, meaning areas of the graph that are darker had more respondents on that survey date with similar answers.

Chapter 2. The Influence of Extreme Weather Events on Perceptions of Personal Experience with Climate Change and Extreme Weather in New York State

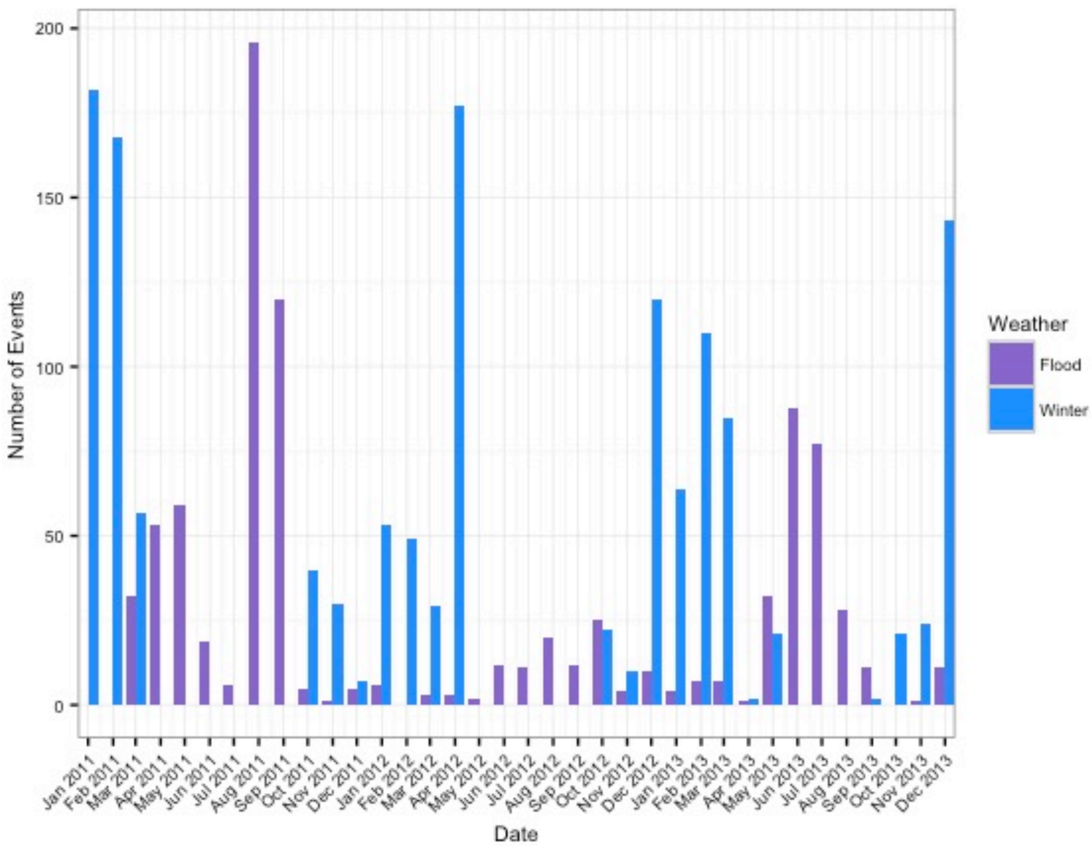

Figure 0.4 The number of extreme weather events for all NYS counties by month for the three years prior to the administration of the 2014 Empire State Poll. Flood events are marked by purple bars, while winter weather and extreme cold events are marked by blue bars. Data are from the NOAA Storm Events Database.

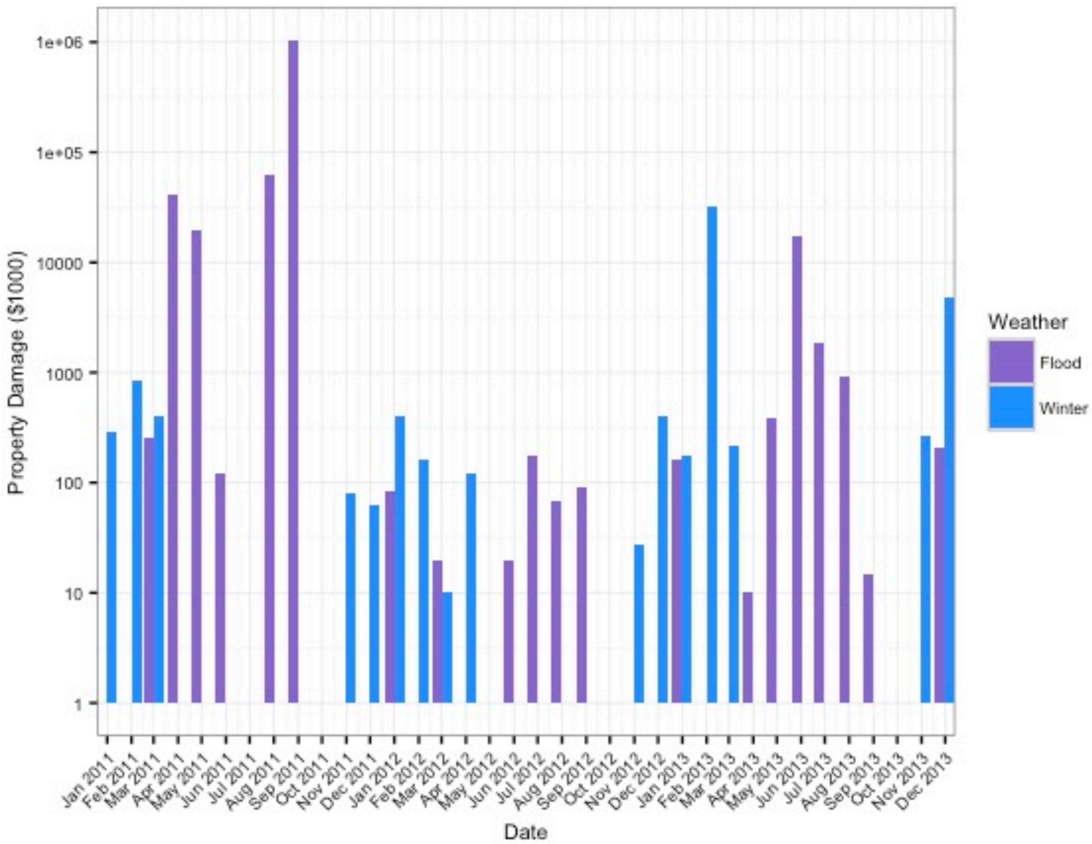

Figure 0.5 Property damage due to extreme weather events for all NYS counties by month for the three years prior to the administration of the 2014 Empire State Poll. Flood events are marked by purple bars, while winter weather and extreme cold events are marked by blue bars. Data are from the NOAA Storm Events Database.