

**Into the Woods: Investigating the Effects of Weather Information and Attentiveness on
Outdoor Recreational Activities**

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

Responses to quick-onset atmospheric weather hazards, including thunderstorms, are influenced by the characteristics of risk messages and the characteristics of the message receivers. Message characteristics relating to the probability of and imminency of thunderstorm impacts, as well as the severity of the information and use of wireless emergency alerts are thought to influence responses through amplifying recipients' risk perceptions. Receiver characteristics relating to past experiences, knowledge and preparedness, sociodemographic characteristics, among others, also play an influential role in the hazard-response cycle. However, the complex role that recipients' attentiveness has in this hazard-response cycle has not been adequately addressed.

This thesis investigates the role that attentiveness and thunderstorm information messaging play in outdoor recreational activity responses. For this investigation, an experiment consisting of a hypothetical hiking activity under an evolving thunderstorm threat was carried out in an online survey of a sample of 476 adult respondents who regularly camp and hike in southern Ontario during the thunderstorm season. Respondents received relevant weather information through a forecast displayed on a smartphone screen before the hike and subsequent watches (1 hour later) and warnings (2 hour later) during the hike, constituting three scenarios. Correspondingly, half of the respondents received a severe thunderstorm watch consisting of higher-severity information and a wireless emergency alert notification with a subsequent severe thunderstorm warning. Respondents' attentiveness, risk perceptions, and behavioural response intentions were recorded following each scenario and comparisons were made between responses from the common and higher-severity message conditions groups to investigate the effect of higher-severity information and WEAs across a thunderstorm event. Receiver characteristics thought to potentially influence observed relationships between attentiveness, risk perceptions, and behaviours during the specific experimental situation were also explored to provide a more complete understanding of the pathways of influence to behavioural responses during thunderstorm events.

Empirical results illustrate that outdoor recreationists are highly attentive and responsive to thunderstorm information; whereas most respondents are unlikely to go ahead with a hike following a weather forecast mentioning the risk of severe thunderstorms. Official severe thunderstorm watch alerts increased respondents' attentiveness to the weather and led to increased proactive protective action likelihoods by most of the remaining participants. Wireless emergency alerts did not change respondents' attentiveness to severe thunderstorm warnings. The pathways of influence to protective actions show that attentiveness amplifies risk perceptions, which acts as a mediator to behavioural response intentions. Individuals' receiver characteristics affected the observed pathways of influence to protective actions. Most notably, respondents' general weather attentiveness greatly amplified their likelihood to be attentive to the weather during a thunderstorm event and amplified their likelihood to take protective actions. The conclusions of this research underscore the importance of attentiveness in the hazard-response cycle and the need for easier accessibility and exposure to weather forecasts and official alerts in outdoor recreational areas to increase attentiveness and desirable behavioural responses.

Keywords: Thunderstorms, Risk Communication, Attentiveness, Risk Perceptions, Wireless Emergency Alerts, Behavioural Responses

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Dedication

For Mom and Dad,

Thank you for the unwavering love and support that has allowed me to follow my dreams.

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List of Abbreviations

SCT – Social Cognitive Theory

PADM – Protective Action Decision Model

WEA – Wireless Emergency Alert

SARF – Social Amplification of Risk Framework

MWA – Mobile Weather Application

Chapter 1

Introduction to the Research Topic

1.1 Problem Context

In the field of environmental geography nature and society are considered to be intrinsically connected. This connection provides both opportunities and risks, the latter in the form of ‘natural’ environmental hazards (e.g., thunderstorms), which continue to negatively impact societies worldwide. Associated impacts include fatalities, injuries, infrastructure and economic losses, as well as the displacement of communities and livelihoods. Such impacts are prevalent and especially problematic in developing countries (UNDRR, 2023). In more economically advantaged regions, such as Canada, impacts tend to be offset, partially, by increased resilience through technological, societal, health-related advances, and risk mitigation measures (UNDRR, 2023).

Risks associated with weather and climate events and conditions, in particular, may be exacerbated by human factors (i.e., individual risk and hazard beliefs, attitudes and emotions, perceptions, knowledge, attention, past experiences, physical barriers, behaviors and practices). Currently, most of the academic literature in geography, social, and behavioural sciences on human responses to weather- and climate-related environmental hazards, and more specifically, atmospheric weather hazards, has focused on these human factors and their influence on societal and individual risk in concert with risk information (Morrow, 2009; Mileti and Peek, 2002; Kox and Thicken, 2017; Silver, 2019; Mills, 2021; Sutton and Wood, 2022). In this field, research on human factors predominantly focuses on how the psychological, social, and demographic characteristics of risk information recipients affect their exposure to, attention to, comprehension of, perceptions of, behavioural decision-making intentions, and actual realized outcomes of hazardous events (Mileti and Peek, 2000; Paton, 2003; Bean et al., 2015; MacIntyre et al., 2021). Researchers have also contributed to understanding the role that the features of risk information messages (Mileti and Sorenson, 1990; Sutton et al., 2020; Riel and Miczo, 2024) and related risk information communication media—human audio-visual senses that pick up on environmental cues (e.g., lightning strikes, smoke from wildfires, or the sound of thunder)—and/or social sources and official alerts (e.g., television, radios, mobile devices, or talking with others) play in

decision-making processes and outcomes (see Lindell and Perry, 2012; Lindell, 2018). **The focus of this thesis is on understanding how to effectively communicate risk to people who may be exposed to environmental hazards; placing this research in the evolving field of study referred to as risk communication** (Lindell and Perry, 2012; Ripberger et al., 2014; Silver, 2019; McGee and Penning-Rowsell, 2022; Sutton and Wood, 2022).

Within the field of risk communication, decades of empirical research has been applied to improve communication practices between experts and the lay public. The outcome of these practices within the context of atmospheric weather hazards is tailored information presented to the public by national meteorological and hydrological services (NMHS) and other non-governmental organizations (Attems et al., 2020; WMO, 2023). The overarching goal of these practices is to increase the likelihood that vulnerable members of the public implement protective actions that reduce risk; which in turn reduces social and economic impacts (WMO, 2023; UNDRR, 2023). Effective risk communication therefore serves as a critical step in reducing vulnerability and building adaptive capacity towards hazards over both the short and long-term (McMartin et al., 2018; MacIntyre et al., 2021). While the advancement of and implementation of ‘best practices’ in risk communication have made substantial progress in the last several decades, elevated risk remains, even in technologically advanced regions, such as Canada (MacIntyre et al., 2021; Krueger, 2022; Bogdan et al., 2024). The Sendai Framework for Disaster Risk Reduction 2015-2030 (UNISDR, 2015) emphasizes that effective disaster risk reduction requires both structural, i.e., infrastructure and technological measures, and non-structural, i.e., risk communication measures. Enhancing risk communication for environmental hazards clearly remains a priority to mitigate adverse impacts to Canadians as noted in Canada’s National Disaster Mitigation and Emergency Management Strategies Report, under the “Public Awareness, Education and Outreach” and “Knowledge and Research” areas of the “Priority Actions for Implementation” section (Public Safety Canada, 2022).

Recent attempts to make sense of people’s differing interactions with and responses to hazards are found in the Canadian and global risk communication scholarly literature (Lindell and Perry, 2012; Silver, 2017; Silver and Andrey, 2020; Weyrich, 2020a; Balog-Way et al., 2020; Mills, 2021; Kasperson et al., 2022; Jit et al., 2023). Theoretical and empirical works within the field have grown extensively in relation to several concepts: risk perception, risk comprehension, risk as feeling, and attention creation. Much of the literature focuses on risk

perception—the subjective interpretation of one’s risk to adverse impacts from a hazardous event (Slovic, 1987). Risk perceptions research distinguishes between perceptions based in either affective, i.e., risk as feeling (Lowenstein et al., 2001) processes rooted in emotion-based and intuitive responses to danger or analytical/cognitive processes rooted in logic and scientific deliberation (Slovic and Peters, 2006). Risk comprehension focuses on people’s understanding of risks with the assumption that greater understanding leads to improved decision-making; assessing risk knowledge levels provides a way to partially evaluate the effectiveness of risk communications (Weinstein, 1999). Recently, risk communication studies have begun to investigate the role that attention creation, the act of selectively focusing on one or more stimuli in one’s external environment, plays in decision-making under risky situations (see Stewart, 2009; Lindell and Perry, 2012; Lindell, 2018; Silver, 2017, 2019; Sutton et al., 2020; Attems et al., 2020). Silver’s (2017) dissertation on attention creation during extreme events, is particularly relevant as it provides initial empirical evidence that attention creation is an important link between communicated risk information and responses, i.e., perceptions and decision-making intentions associated with extreme atmospheric weather hazards—primarily those associated with thunderstorms.

Other attempts at explaining interactions between risk information and responses have focused on the inclusion of other individual receiver characteristics/constructs that vary across individuals, e.g., personality traits (Bolton et al., 2022), cultural and religious beliefs (Gierlach, 2010), weather salience (Stewart, 2009; Stewart et al., 2012), weather curiosity (Stewart, 2017), or one’s inherent need to be weather-connected (Bolton, 2021). These factors are thought to moderate or mediate the observed relationships among risk information, social and psychological factors, and responses—providing further explanations of the variability among influential pathways. Empirical research applying related concepts have identified risk communication interventions that more efficiently elicit desirable protective action decision-making responses, which may be thought of as measurable physical actions taken (or not taken) to reduce exposure to hazards (Lindell & Perry, 2012; Lindell, 2018). Synthesis of findings has led to several conceptual frameworks, derived from behavioural theories (e.g., social cognitive theory by Bandura, 1986, protection motivation theory by Rogers 1975, 1983, health belief model by Becker, 1974, and theory of planned behaviour by Ajzen, 1991), that attempt to explain the dynamic interactions among hazards, risk information, social and individual factors, and

desirable protective actions. These include the social-cognitive model of disaster preparedness by Paton et al., 2003, the protective action decision model by Lindell and Perry, 2012; Lindell, 2018, and the conceptual model of attention creation during extreme events by Silver 2017; Silver and Andrey 2019). Importantly, theory-based conceptual frameworks remain critically underutilized in risk communication studies of environmental hazards and responses with limited use of relevant explanatory variables and analyses of their complex relationships (Ejeta et al., 2015; Lindell, 2018) and calls have been made for further empirical insights (Donner et al., 2012). Empirical testing of these conceptual frameworks can determine factors that warrant improvements and introduce related interventions; improving risk communication and hazard management.

Despite the plethora of research on the relationships between a myriad of human factors, related implemented interventions, and their role in reducing risk within the risk communication and environmental hazard's literature, a small segment of members of the public have been shown to be, at times, inattentive or non-responsive to impending risks. This current affair in risk communication research was highlighted by Silver (2017, pp. 139), who concluded that, “the fact that some individuals attend to warning information and environmental cues while others do not is an ongoing topic of interest within the hazards literature.” The inability of existing research to substantively explain the variability in hazard responses within different contexts raises one important investigative question: what other factors may play a role in linking the information provided by a hazard itself, risk communications, and protective action responses?

One such characteristic with promising applicability to the hazard-response cycle is one's continual cognitive engagement with stimuli/phenomena over time (i.e., attentiveness) and how it influences decision-making and associated behavioural responses during hazardous events evolving across space and time. This is important, given that hazards do not occur over a single period in time, usually expressing cues before impacts are felt in conjunction with increasingly urgent information as hazard threats develop. ‘Attentiveness’ is different from the act of ‘attention’ as defined by Silver (2019: 301) as, “the process of noticing, selecting, and focusing on one or more external stimuli (e.g., hazardous event or event-related information) to which people are exposed.” While a review of recent English-language publications did not reveal any studies on the relationship between environmental hazards and attentiveness, several recent studies exist on the role that attentiveness plays in other human-environment interactions, such as

agriculture (Alarcon and Marty, 2023), and resource provisioning (Pakan, 2022). The conclusion of these studies is that attentiveness enables people to adjust responses based on changes in their environment and within the context of their situation and goals. For example, Alarcon and Marty (2023) found that by increasing farmers' attentiveness to relationships between agricultural plots and nature, they diversified plantings, increased crop yields, better adapted to weather changes, and reduced pesticide usage. Attentiveness has been found to be important in linking information received and outcomes of different kinds (Klaver and Baart, 2012). For example, attentiveness has been shown to be influential in positive outcomes, such as improved social connections (see Coker, 1983), learning (see Derakhshandeh et al., 2021), psychological health (Reynolds, 2008; Murtaza et al., 2022), ethical behaviours (Reynolds, 2008, 2015; Halbusi, 2022), environmental ethics (Krzywoszynska, 2019), construction safety (Kim et al., 2021), and patient/health care (see Klaver and Baart, 2012).

There is a clear need to examine the role of attentiveness as a human factor in the hazard-response cycle in the design of effective risk communication. More specifically, its influence on individuals' responses during quick-onset weather events is needed to provide a more complete picture of the interactions between risk information, human factors, and behaviours. Weather attentiveness comprises individuals' sensitivity to perceive weather-related elements during events and experiences (a conceptual definition of weather attentiveness is provided in section 2.2.6). Drawing on Social Cognitive Theory (Bandura, 1986) and an agentic perspective, this thesis posits that by chronically filtering experiences through a weather-related lens (i.e., high weather attentiveness), individuals may pay greater attention to weather-relevant aspects during the evolution of events by noticing relevant changes, then perceiving their risk, and then taking proactive protective actions.

Understanding the role of attentiveness in responses to hazardous weather events may be best evaluated in risky settings, where people are likely to be exposed to the onset and potential impacts from evolving weather hazards, i.e., outdoor areas. Research in the setting of outdoor areas also inherently reduces confounding factors on protective actions given that there are limited possible options. Thus, outdoor recreational activities, such as camping and hiking provide an opportunity to examine the influence of attentiveness and other human factors on decision-making in the presence of short-notice, high-risk environmental hazards, such as thunderstorms. Additionally, this research setting provides a pragmatic approach into initial

insights of the effectiveness of wireless emergency alerts (WEAs) on responses to severe thunderstorm warnings when outdoors given their unignorable alerting aspects audibly, visually, and physically (i.e., vibrations) (Alert Ready, n.d.). Outdoor recreational activities also serve as a major economic and social asset in many countries, such as Canada, where nature-based tourism in provincial and national parks in Canada serve millions of visitors each year, with numbers continuing to grow (Parks Canada, 2023). Provincial Parks in the Canadian Province of Ontario attract over 10 million visitors, annually, with visits concentrated in the southern corridor of the province, southern Ontario (Ontario Parks, 2023). Within these natural areas, visitor numbers, satisfaction, and safety are highly dependent upon climate and weather-related factors and related risks (Scott and Lemieux, 2010; Hewer, 2012; Reining, et al., 2021; McFadden, 2021). Accordingly, calls have been made to better understand the risks posed and related responses from visitors in these areas to hazardous weather events due to the lack of social science studies within Ontario (Canadian Parks and Wilderness Society, 2020).

Thunderstorms are a common meteorological phenomenon characterized by the presence of lightning (ECCC, 2019) and can include cloud-to-ground (CG) lightning, straight-line winds, large hail, intense rain, and occasionally, tornadoes; all of which can be hazardous to people. Thunderstorms occur in both tropical and temperate regions, globally. In North America, thunderstorms occur most often and are most severe in an area extending from Texas then north to the Canadian Prairies and Great Lakes regions (Orville, 2011). In Canada, Western Alberta, southern Manitoba and Saskatchewan, and southern Ontario are the most active regions for thunderstorm activity (see Figure 1). Currently, southern Ontario experiences an average of 10 to 20 thunderstorm days, annually, with some inhomogeneity due to geographic influences from the Great Lakes (Huang et al., 2021). These storms occur most frequently along a southern Ontario corridor that extends from Windsor to Ottawa with a hotspot extending from Windsor to London, Ontario, as represented by historic lightning data (Kochtubajda and Burrows, 2020) (See Figure 1). Thunderstorm season occurs from April to September, peaking in June and July in southern Ontario (ECCC, 2016). Thunderstorm-related casualties in Canada are related for the most-part to cloud-to-ground lightning, though damaging winds, tornadoes, flooding, and hail have also led to casualties (Mills, 2008, 2020). Casualties are most prevalent among outdoor recreationists and outdoor workers (Mills, 2020).

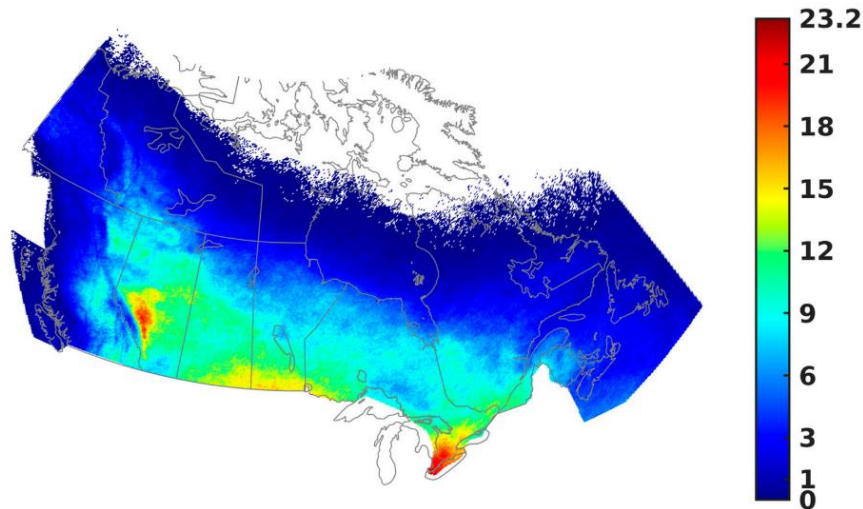


Figure 1. Average number of days with recorded cloud-to-ground (CG) lightning in Canada (Kochtubajda & Burrows, 2020).

Southern Ontario, Canada, regularly experiences severe hydro-atmospheric events, particularly, damaging thunderstorms (Huryn et al., 2020). In 2022 alone, insured losses of \$3.1 billion were incurred in Canada from 15 weather- or climate-related catastrophic events, four of which impacted southern Ontario (CATIQ, 2023). One of the most impactful thunderstorm events was a severe straight-line wind phenomenon, known as a derecho, that swept across the Windsor-Quebec City corridor on May 21st, 2022. This event was implicated in 12 deaths and at least 12 other injuries (NTP, 2023) and accounted for ~\$1 billion in losses alone, making it the 6th largest insured loss in Canadian History (CATIQ, 2023). Most of the casualties from the holiday weekend event were those engaged in outdoor activities and injured by falling trees or tree branches (CBC, 2022). The coincidence of peak thunderstorm frequency in the summer months (Kochtubajda and Burrows, 2020) and Southern Ontario's plethora of outdoor recreational activity areas (e.g., Provincial and National Parks) and visitors (Ontario Parks, 2023) provides an opportunity to build a plausible scenario and experiment to investigate the role that weather attentiveness plays in behavioural and protective action intentions.

1.2 Study Purpose, Research Objectives, and Activities

The purpose of this thesis is to empirically investigate the influence of weather attentiveness and thunderstorm risk messaging on individual trip and recreational activity responses (i.e., situation-specific risk perceptions and behaviours) across an evolving thunderstorm event. The specific focus is on official government-issued thunderstorm forecasts, watches, and warnings, in the context of planning and/or engaging in outdoor recreational activities, namely day-hiking activities within a Provincial Park. Additionally, the influence of several general human factors, referred to in the remainder of this thesis as receiver characteristics, are investigated to provide a more complete understanding of the pathways of influence to protective actions during thunderstorm events. Receiver characteristics to be investigated include: general weather attentiveness, general weather salience, general thunderstorm hazard perceptions, past thunderstorm experience, general thunderstorm knowledge and preparedness, general communication media usage and preference, and sociodemographic characteristics (i.e., age, education, gender, and Ontario residency length). While the study is focused on thunderstorms in southern Ontario, the research methods adopted, and empirical findings are relevant and contribute to the understanding of a broader set of natural and environmental risks in Canada and internationally. As such, the research seeks to meet several research objectives:

1. Determine the general receiver characteristics of a subpopulation of southern Ontario adults that regularly engage in camping and hiking outdoor recreational activities.
2. Investigate the influence of thunderstorm messaging on attentiveness during outdoor recreational activities.
 - a) Investigate changes across time during an evolving thunderstorm event, i.e., from a forecast to a watch to a warning.
 - b) Investigate the influence of thunderstorm messaging for common vs. higher severity watches and warnings.
3. Identify and quantify the pathways of influence affecting responses to thunderstorm messaging.

- a) Model the influence of potentially influential general receiver characteristics on general weather attentiveness.
- b) Model the influence of situation-specific attentiveness on decision-making.
- c) Model the influence of general receiver characteristics on situation-specific attentiveness, risk perceptions, and decision-making.

These objectives are met in this study through several research activities:

1. Operationalize the concept of attentiveness in the context of weather risk communication pertaining to environmental hazards through a review of the relevant theoretical and empirical literature.
2. Critically review influential factors on responses to risk information, emphasizing studies pertinent to thunderstorms.
3. Through a survey, collect data on influential factors in the hazard-response cycle of thunderstorms and determine how they effect weather attentiveness, risk perceptions, and behavioural responses.
4. Through an experiment, test if weather attentiveness plays an influential role in thunderstorm responses in conjunction with other general receiver characteristics.

1.3 Theoretical Framework

To explain and test the influence of weather attentiveness and thunderstorm risk messaging on responses, the study draws upon concepts from social cognitive theory (SCT) and relevant conceptual models used in the risk communication literature, i.e., the protective action decision model (PADM) and model of attention creation during extreme events. A theoretical framework presents a strong guiding basis for social science studies because, “It specifies the determinants of psychosocial change and the mechanisms through which they produce their effects. This knowledge provides the guiding basis for effective change.” (Bandura, 2012: 369).

SCT, developed by Albert Bandura (1986) is aimed at understanding the dynamic interactions between people’s personal characteristics (i.e., weather attentiveness, weather salience, weather knowledge, sociodemographic characteristics, among others), their environment (official weather messages, social and environmental cues, situational/contextual

factors), and their behaviours (protective actions) across time and space. SCT has been used as a theoretical foundation for several studies within the environmental hazards and risk communication literature because of its central understanding of the role of individual human agency, i.e., people proactively make decisions and carry out behaviours to alter outcomes of events (Bandura 2012). For example, Paton, (2003) used SCT as a theoretical foundation to develop the social-cognitive preparation model—an attempt at explaining why risk perceptions did not always align with environmental hazard preparedness by considering inherent cognitive processes underpinning behaviours. More recently, Silver (2017, 2019, 2020) used SCT as a theoretical basis to develop and conceptualize how attention is created across space and time in response to one’s direct or indirect exposure to information regarding an extreme event. Other applications of SCT in the environmental hazards literature include additional studies on disaster preparedness (Espina and Teng-Calleja, 2015; Kitagawa, 2021; Cai et al., 2023; Davarani, 2023), and information-seeking (Li and Guo, 2016), which provided additional insights into how behaviours are a result of differing individual characteristics, external stimuli, and the interactions between them (Bandura, 1986, 2012; Fiske and Taylor, 2017).

As applied to environmental risk communication, SCT advances the understanding into what characteristics lead to greater interactions with risk communication information and how these characteristics influence protective action behaviours across evolving situations and stimuli. As such, using SCT as a foundational basis, this thesis is oriented according to a conceptual model that synthesizes the scholarly understanding of interactions between influential factors in the hazard-response cycle for atmospheric environmental hazards and builds upon existing gaps by introducing the potential influential role of weather attentiveness on responses. Figure 2. showcases the conceptual framework of this thesis according to a causal diagram, specifying the related pathways of influence to be investigated for this study.¹

¹ While other factors may be important in the hazard-response cycle for outdoor recreationists (e.g., risk tolerance) (Gatti and Brownlee, 2024), only the factors used in this particular study are noted in the conceptual framework.

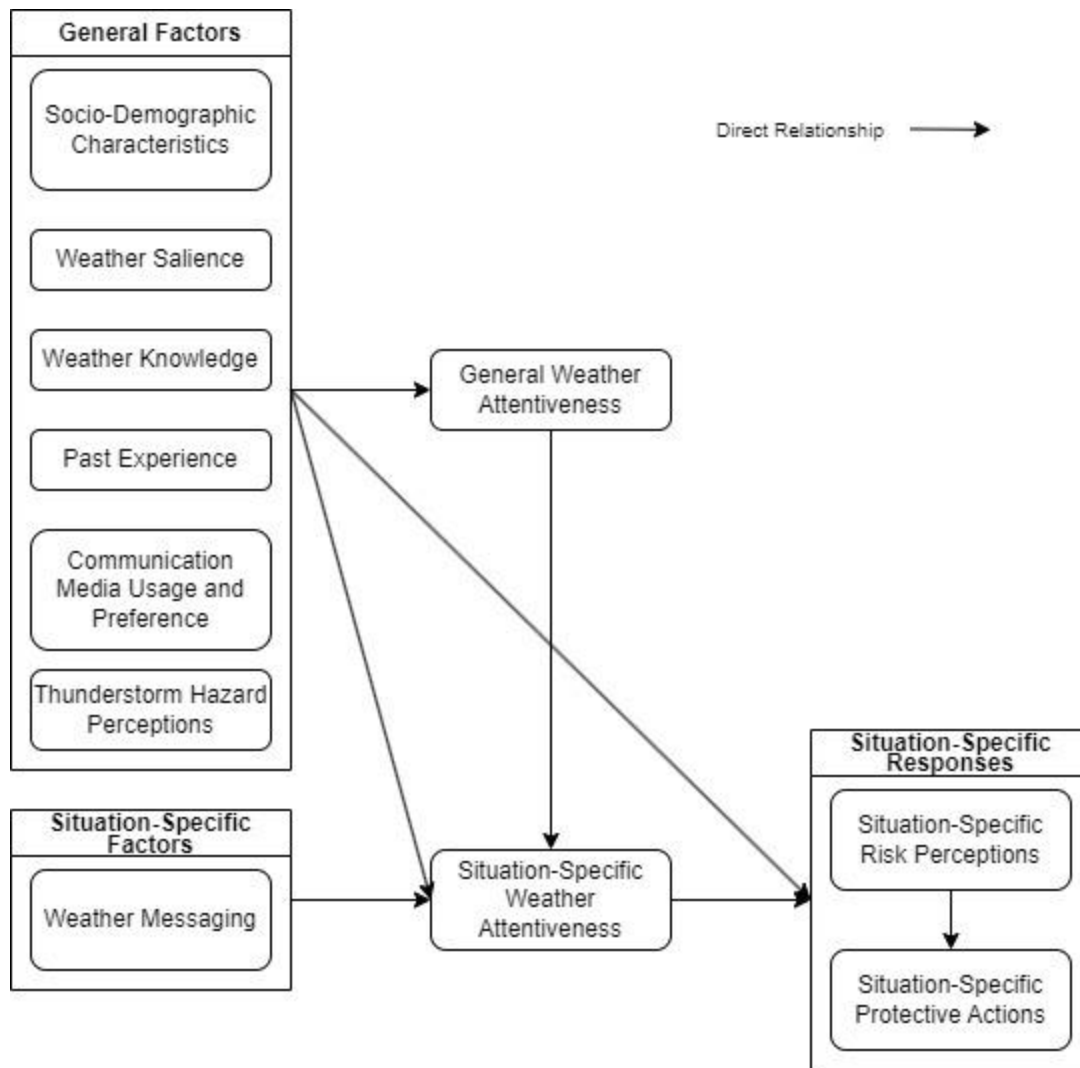


Figure 2. Conceptual framework of the proposed study.

1.4 Research Scope

The empirical elements of this thesis aim to contribute to the scholarly body of work in risk communication by investigating, through a social cognitive theory lens, the role that weather attentiveness and risk messaging plays in the hazard-response cycle in conjunction with other interacting receiver characteristics and situational factors. Applying these findings may allow for improved education surrounding thunderstorms and provide increasingly effective risk communication(s). The Canadian context of this research also provides valuable contributions to Canada’s recently embraced “whole-of-society” approach to risk mitigation through a better understanding of risk communication needs and priorities as set out by Canada’s National Disaster Mitigation and Emergency Management Strategy (Public Safety Canada, 2022). Given

the limited previous related work on thunderstorm risk messaging and outdoor recreational activities across a wide variety of disciplines that study human behaviours (notable exceptions include Weyrich, 2020a, 2020b), this study is exploratory in nature to examine the influence of multiple factors on outcomes. This research also contributes to the Canadian Parks Research Network initiative, a PARKS+ Collective Research Network (Canadian Parks Council, 2024), which aims to implement empirically based research findings into decision-making; advancing the safety and positive impacts of protected areas in Canada.

1.5 Thesis Format

This manuscript is written in a traditional thesis format for the social sciences, with an opening chapter (Chapter 1) that introduces the problem. Chapter 2 focuses on the relevant theoretical and empirical literature; overviewing what has been done and what gaps exist regarding attentiveness in the hazards and risk literature. Chapter 3 provides an outline of the empirical methods and experimental elements of the study. Chapter 4 is used to discuss and document the empirical results of this study. Chapter 5 provides a summary and interpretation of the results, linking them to relevant literature on the topic(s), the contributions of the research, as well as avenues for future research.

Chapter 2 Research Context and Theoretical Considerations

This chapter introduces and examines the extant literature relevant to risk communication, attentiveness, decision-making, and the impact of environmental hazards on outdoor recreational activities. Concepts related to environmental hazards and risk are first introduced through the lens of environmental geography. Next, the chapter discusses relevant risk response paradigms: the psychometric risk paradigm, social amplification of risk framework, protective action decision model, and model of attention creation during extreme events to frame the process and observed influential factors in the hazard-response cycle. This is followed by a review of relevant human factors, namely weather salience, past experience, sociodemographic characteristics and knowledge and their influence on responses concerning environmental hazards. Next, attentiveness is operationalized from the perspective of weather hazards and differentiated from other concepts, and literature from fields outside of environmental hazards is used to provide rationality for further inspection in the environmental hazards literature. More specifically, ‘attention’ and ‘attentiveness’ are compared, from a variety of theoretical backgrounds and disciplines, to showcase differences, similarities, and applications for environmental hazards research in the context of risk communication. Next, the chapter summarizes the risk communication process and media usage regarding thunderstorms in broadly and internationally, in Canada. Lastly, the chapter summarizes the literature on the relationship between weather and outdoor recreational activities and existing research gaps.

2.1 Environmental Geography

Environmental geography is a subfield within the discipline that arose in the early 20th century (Castree et al., 2009) from the need to better understand interactions between people and the natural world due to the cascading effects of environmental degradation and disasters on society during the 20th century (Harden, 2012). Occupying the ‘middle ground’ between human and physical geographies (Demeritt, 2008; Castree et al., 2009; Andre, 2017), the field draws from both the social and physical sciences to study interactions between human activities (e.g., hiking) and their surrounding natural environments (e.g., thunderstorms) (Harden, 2012; Zimmerer and McSweeney, 2020). While subjective, some of the interactions between societies and their environments are viewed as beneficial (e.g., sustainable ecosystem management and ecosystem services), while others are framed as being detrimental (e.g., environmental hazards

and environmental degradation) (Harden, 2012). For example, someone who loses their home to the natural phenomena, river flooding, views the interaction as negative, labelling it as an environmental hazard, whereas ecologists may consider the event as a beneficial environmental disturbance, given the ecosystem benefits provided (e.g., increased soil fertility and removal of overgrown vegetation).

Over time, the study of these complex human-environment interactions has resulted in several environmental concepts, including, sustainability, environmental perception, anthropogenic environmental change, environmental degradation, anthropogenic pollution, biodiversity loss, environmental governance, environmental justice, and environmental psychology, among others. As such, environmental geography serves as a crucial discipline for increasing the understanding of current human-environment challenges and the solutions needed to address them at multiple scales and landscapes across the planet. The need to better understand and address environmental challenges through the conceptual basis of environmental geography is especially pertinent to the study of environmental hazards, given their increasing threat to human societies (Gunjyal et al., 2023) and need to better understand specific relationships and processes to support risk mitigation and adaptation to their impacts (Donner et al., 2012; UNDRR, 2023). Such investigations are enhanced, in part, by behavioural and cognitive geography approaches, which take into account ‘lay reasoning and beliefs to understand how people respond to threats and opportunities in and concerning space and place’ (Montello, 2018: 3).

2.1.1 Introduction to Environmental Hazards

Environmental hazards are broadly defined as “natural processes that interact with people in an impactful and negative way” (Keller et al., 2012: 12); or, alternatively as, “all the potential threats facing human society by events that originate in, and are transmitted through the environment” (Smith and Petley: 9, 2013). A review of the extant literature on environmental hazards highlights four critical elements of environmental hazards: (1) they involve natural earth processes and phenomena that have the potential to result in consequential events, (2) threaten human lives and developments, (3) become hazardous to society because of human exposure on landscapes where they occur, and (4) require some level of vulnerability by humans to result in

adverse consequences to humans (Keller and DeVecchio, 2019; Montz et al., 2017; Muir-Wood, 2016; Smith, 2013).

Environmental hazards may be thought of as comprising two geophysical groups: solid Earth and atmospheric processes (Keller et al., 2012). Solid Earth processes, resulting from exchanges in earth's internal energy with the surface, lead to geophysical hazards, namely, earthquakes, tsunamis, and volcanoes, which occur most commonly at or near plate tectonic boundaries and weak spots in Earth's crust (McGee and Penning-Rowsell, 2022). Alternatively, atmospheric processes, which result from the exchanging of the sun's energy near Earth's surface (i.e., within the troposphere), encompass the Earth's climate and weather events, leading to what are referred to as hydro-meteorological/climatological hazards, namely floods, wildfires, tropical cyclones, blizzards, extreme temperatures, droughts, thunderstorms, and tornadoes (McGee and Penning-Rowsell, 2022).

Hazardous events are the realization of a threatening condition—exceeding the resiliency of the human system(s) and may include a single hazard or multiple hazards simultaneously (Dalezios and Lalenis, 2017; Van Westen and Greiving, 2017). For example, a thunderstorm event may include a tornado, hail, heavy rain, and lightning that strikes the ground. Additionally, hazardous events can be either slow- or quick-onset. Slow-onset events, such as droughts or river flooding, occur over large spatio-temporal scales and generally allow higher predictability of impacts and more thought-out adaptive responses, such as evacuations (UNDRR, 2022). Quick-onset events, such as thunderstorms or flash floods, leave little time for people to respond and are generally less predictable due to their occurrence at small spatio-temporal scales (UNDRR, 2022). The occurrence, intensity, magnitude, duration, frequency, and speed of onset of these natural processes responsible for hazards vary regionally. For example, the clashing of cold air from the snow-covered Rocky Mountains and warm, moist air from the Gulf of Mexico meet seasonally in the central United States, creating large storm systems every spring and fall; resulting in more tornadoes, annually than anywhere else on the planet (Mileti and Sorensen, 1990).

Hydro-meteorological/climatological hazards remain a substantial threat to society, accounting for ~45% of all disaster event deaths and 74% of related economic losses during the 1970 to 2021 period (WMO, 2021). In 2022, weather-related disaster events resulted in nearly

29,000 deaths worldwide and around \$211 Billion (USD) in economic losses (CRED, 2023). Although the economic losses from atmospheric events have risen, especially in the most developed regions (O'Brien et al., 2006; WMO, 2021; CRED, 2023), injuries and fatalities have generally decreased (exceptions include major disaster events, such as the European heatwave in 2022 (CRED, 2023)), becoming concentrated in the least developed countries. Rising economic costs are concentrated in the most developed areas (O'Brien et al., 2006; IPCC, 2021; WMO, 2021; CRED, 2023).

2.1.1.1 Evolution of Environmental Hazard Perspectives and Human Agency

In the academic literature, some of the earliest thinking on the explicit connection between human activities and impacts from environmental hazards were proposed by Prince (1920) and Carr (1932) following the first systematic post-disaster studies and exemplified in Gilbert F. White's (1945) PhD dissertation and accompanying publication on flood management, where he famously stated, "Floods are 'acts of God,' but flood losses are largely acts of man." White (1945) argued that human encroachment on floodplains is what accounts for high flood losses. His position, that societal impacts of natural events are not purely 'natural' and instead are a result of human actions, was radically different than previous schools of thought pre-dating the early 20th century, where environmental hazards were seen as something largely outside of human control—except through technocratic efforts (i.e., the building of large dams to control water flow).

Today, the dominant view, an extension of White's original thesis, is that human factors largely determine the individual and societal impacts of environmental hazards (White et al, 2001). However, some discourse remains in the literature on the proportional attribution of human factors and environmental processes on societal impacts, as a whole (see Perry, 2018). Human factors are myriad: infrastructure vulnerabilities, as a result of poor or outdated engineering standards, human developments within hazard zones, low proactive disaster preparedness and resilience activities, distorted perceptions of hazard risks, and the miscommunication and misunderstanding of hazard risk (Smith, 2013; Muir-Wood, 2016; Keller and DeVecchio, 2019). Increasing emphasis on the role of human agency on impacts has shifted the focus of research towards the social dimensions of risk.

Impacts are associated with ‘social vulnerability’ i.e., the “characteristics of a person or group in terms of their capacity to anticipate, cope with, and resist and recover from the impact of a natural hazard” (Blaikie et al. 2003: 11). Some studies have aggregated social characteristics, creating a social vulnerability index (SoVI) (Lehnert et al., 2020). Social vulnerability index’s include four types of characteristics: socio-economic status, household composition and disability, minority status and language, and housing and transportation (Lehnert et al., 2020). The assessment of social vulnerability has allowed researchers and practitioners to separate the biophysical dimensions of hazards from the social dimensions (Otto et al., 2017; Mah et al., 2023).

2.1.1.2 Environmental Hazards and Climate Change

From both a social and economic standpoint, anthropogenic climate change, in combination with the influences of other anthropogenic factors (i.e., increased population growth, urbanization, social vulnerabilities, and land use pressures leading to environmental degradation) is expected to exacerbate the impacts of hydro-meteorological hazards globally (IPCC, 2021; McGee and Penning-Rowsell, 2022). As the IPCC clarified:

“Human-induced climate change is already affecting many weather and climate extremes in every region across the globe. Evidence of observed changes in extremes such as heatwaves, heavy precipitation, droughts, and tropical cyclones, and in particular, their attribution to human influence, has strengthened since AR5².”

(IPCC, 2021: 10).

To reduce the impacts of climate change and build resilience, the IPCC (2021) advocated for continued advances and investment in social and ecological activities, namely disaster risk management with a primary focus on risk communication, green infrastructure, and social capital. By increasing the implementation of disaster risk management activities with a primary focus on increasing the effectiveness of risk communications, risk reduction for environmental and climate-related hazards becomes more proactive. As a result, risk management is less reliant on large-scale hard infrastructure that is generally costlier, has a higher human and

² The previous IPCC publication of the amalgamated evidence of human attribution to observed global climate extremes (IPCC, 2014).

environmental impact, is reactive (IPCC, 2021), and at times has been shown to provide an inflated sense of security, i.e. the *levee effect* (see Burton et al., 1968; Di Baldassarre et al., 2015; Aerts et al., 2018; Hutton et al., 2018; Roessing-Anderson, 2023).

2.2 Social Dimensions of Hazards

2.2.1 Risk Overview

While environmental hazards encompass threats from the natural environment, the combination of probability/likelihood and consequence/impact constitutes *risk* (Slovic & Weber, 2002; Smith, 2013; UNDRR, n.d.). Risk is comprised of three essential components: (1) the presence of a hazard, (2) human exposure to that hazard, and (3) the vulnerability of the exposed population (Morrow, 2009). These components of risk can be defined as such:

- The occurrence of a hazard: A threat from the environment based on natural processes that has the potential to result in adverse impacts (Keller et al., 2012).
- Exposure: An individual's or a population's presence in an area where hazards can occur (Cardona et al., 2012; CCA, 2022). For example, the very presence of individuals outdoors in an area where thunderstorms could occur represents thunderstorm exposure.
- Vulnerability: The 'propensity to be adversely affected' when an individual or population is exposed to a hazard (IPCC, 2012; UNISDR, 2015). Vulnerability focuses on individual characteristics that make them susceptible to increased exposure and adverse impacts from hazards. For example, pre-existing health conditions and/or decreased thunderstorm preparedness and knowledge may increase one's vulnerability to thunderstorms when outdoors.

This interpretation is consistent with international (UNISDR, 2015) and national (e.g., Public Safety Canada's (2023) definitions of risk.

Risk Management requires an understanding of all three components of risk. It refers to the physical and social processes, namely policies, practices, and resources, used to reduce risks associated with activities that expose one to a hazard(s), reducing negative impacts (Penning-Rowsell and Becker, 2019). Risk assessments provide the foundation for risk management by comprehensively characterizing risks according to stakeholders' values, objectives, goals, and

decision-making requirements (Penning-Rowsell and Becker, 2019). As shown in Figure 3, risk assessments generally follow four phases: scoping, risk identification, risk analysis, and risk evaluation (UNDRR, 2022).

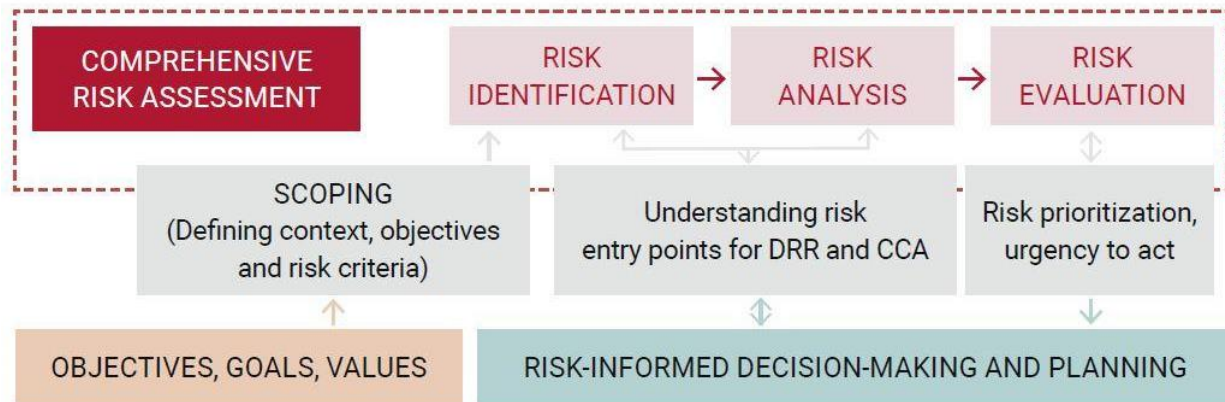


Figure 3. Phases of a comprehensive risk assessment according to UNDRR (2022).

Methodologies for assessing risk for environmental hazards can be complex (see Westen and Greiving, 2017), and assessments vary between hazards. Technological advancements in hazard forecasting and uncertainty estimates have generally increased the quality of inputs into assessments, but challenges still exist. For example, meteorological research into thunderstorm formation, short-term weather prediction models, and weather technology tools, such as radar or satellite continue to advance in many areas, but the ability to accurately predict the location, timing, and severity of thunderstorms remains imperfect (WMO, 2022; Brotzge et al., 2023). Hazards with quick onsets and rapid changes in severity currently provide limited time for provisioning of relevant risk communications and protective messages to vulnerable end-users (Qin et al., 2023).

Social and behavioural scientists are increasingly emphasizing the integration of risk assessments with risk management practices to improve hazardous event outcomes through increasing public trust, communications of risk, and information needed to take protective actions for quick onset environmental hazards, especially thunderstorms (Balog-Way et al., 2020). Risk management practices encompass attempts to manage the negative consequences of hazardous events (Różycki, 2019). Practices are separated into two categories, structural (i.e., protective structures) and non-structural (i.e., educational resources, policies, and risk

communication methods). Both practices aim to reduce exposure by preventing the occurrence of risky activities in the presence of hazards (i.e., risk prevention Public Safety Canada, 2023) or minimizing risk if avoidance of a hazard is not possible (Sutton, 2023). Risk management practices encompass positive human responses to risk, which manifest in decisions and related behaviours intended to reduce risk; responses generally referred to as protective actions (Lindell and Perry, 2012). In regards to thunderstorms, protective actions may include taking shelter inside a sturdy building, staying away from high exposure points when outdoors (e.g., cliffs, open fields, water bodies), or deciding to not participate in activities that could pose a risk.

Despite the implementation of risk management activities for environmental hazards, risk researchers have demonstrated through extensive study on human responses to environmental hazards that, when faced with risks, people often make suboptimal decisions, from a purely rational perspective (Burton, 1978; Fischhoff, 1995; Weber, 2006; Silver, 2019). This thinking, built on the ideas of bounded rationality proposed by Simon (1955), which states that economic decisions are rational to an acceptable level of satisfaction given the information available, became exemplified in the context of environmental hazards by Slovic, Kunreuther, and White (1974). It led to several decades of scholarly works aimed at better understanding why individuals' behavioural responses to environmental hazards differ, with a focus on risk perception (Slovic, 1987; Stewart et al., 2012; Wachinger et al., 2013; Dewitt et al., 2015), attention (Ripberger et al., 2014; Silver 2017, 2019; Sutton et al., 2020), interpretation and knowledge (e.g., Nunley and Sherman-Morris, 2020; Broomell, 2020), risk communication practices (Miletti and Sorensen, 1990; Lazo et al., 2009; Pidgeon and Fischhoff, 2011; Casteel and Downing, 2013; Potter et al., 2018; Weyrich, 2020a; Harrison et al., 2021; Sutton et al., 2021, 2023), and their role in protective action responses (Lindell and Perry, 2012; Silver, 2012; Demuth et al., 2018; Weyrich, 2020a; Mills, 2021).

2.2.2 Risk Communication

Risk communication, considered a necessary component of risk management, aims to effectively deliver relevant information to vulnerable members of the public in ways that motivate effective responses through informed decision-making (Morgan et al., 2002; McComas, 2006). The National Oceanic and Atmospheric Administration defines risk communication as, “An iterative exchange of information among individuals, groups, and institutions related to the

assessment, characterization, and management of risk.” (NOAA, 2019: 2). At its core, risk communication research focuses on understanding the role that individual (i.e., endogenous) characteristics and exogenous factors have on influencing responses to risk, testing related interventions, and integrating empirical and theoretical findings into risk communication practices (Fischhoff, 1995). Several theoretical frameworks and empirical works have aided in understanding the most influential factors in responses to risk(s), guiding current communication practices and providing a basis for further improvements. Morgan et al. (2002) amalgamated relevant theoretical and empirical works, producing the mental models approach to risk communication; a systematic causal model that identifies influential factors on risk and responses based on expert opinion and then compares them with public interpretations to identify gaps and introduce interventions. The plethora of risk communication literature that followed has led to current ‘best practices’ that result in informational risk messages, tailored to the social and geographical needs of the audience (Martin et al., 2007; NOAA, 2019). More specifically, contextual risk information before and during risky events that is meant to allow laypersons to make sense of risk(s) in tandem with their direct observations (Morgan et al., 2002). Resulting risk communications are meant to gain attention, influence risk perception responses, and mitigate the risk of vulnerable public members through motivating and providing the necessary instructions for effective protective actions (NOAA, 2019). Scholarly works in risk communication focus on four main areas that influence responses:

- Message characteristics: The components of messages themselves, including the information included and the presentation of that information.
- Messenger Characteristics: Include the communication media used to disseminate risk messages and the characteristics of stakeholders involved in the creation and transmission of information.
- Receiver Characteristics: The individual physical, social, and cognitive characteristics of message receivers.
- Message Environment: The situational aspects of the external environment that a receiver finds themselves in across the risk communication process; include social, cultural and natural environments and contexts.

2.2.3 Risk Perception

Early works in risk communication found that human responses to risk information, including the protective actions they take to reduce risk(s) are shaped, in part, by risk perceptions (Fischhoff, et al., 1978; Slovic, 1987). Risk perceptions are individuals' personal interpretations of risk, i.e., their judgements, thoughts, and feelings about risks, and are considered a 'critical cognitive function that aims to allow people to be sensitive to, evaluate, and respond to hazards' (Tooby and Cosmides, 2008; Boyer and Bergstrom, 2011; Mrkva et al., 2021). Risk perceptions carry "subjective" aspects of individuals' risk evaluations, i.e., of the hazard(s), their exposure, and their vulnerability, the outcomes of which are public evaluations that are sometimes inconsistent with "objective" facts about risks from official risk assessments (Slovic, 1987; Aerts et al., 2018). Risk perception studies dominate the risk communication theoretical and empirical literature. Empirical studies conclude that (1) risk perceptions, in part, shape the level of risk that individuals are able to tolerate before responding, i.e., taking protective actions, and (2) perceptions vary from person-to-person based on a complex of underlying human factors (Slovic, 1987; Sjöberg, 1999; Lindell and Perry, 2012; Wachinger et al., 2013; Lechowska, 2018).

2.2.4 Main Theories of Risk and Social Responses

Several prominent theoretical frameworks attempt to provide an understanding as to why risk perceptions vary and how they influence protective actions: (1) the psychometric paradigm of risk, (2) the social amplification of risk framework, (3) the protective action decision-model, and (4) the model of attention creation, which is framed according to SCT. The former two frameworks are attempts at quantifying risk perceptions and the affective, cognitive, and social factors that influence them, while the latter two frameworks outline the processes and influences on decision-making responses in the context of risk communication. The latter theoretical frameworks highlight causal relationships among a myriad of explanatory variables involved in linking risk information to risk perceptions and behavioural responses; providing partial explanations for the observed variability in responses. Applied to the hazard-response cycle these frameworks can be used to identify research gaps and integrate untested variables that could explain variability in responses to risk information (Paton, 2003; Rodriguez et al., 2007; Silver, 2017; Weyrich, 2019). The proposed relationships could then be investigated through empirical

examinations that simultaneously test the influence of specific environmental, social, and individual factors on responses. Furthermore, by integrating these frameworks into practice, the behavioural responses of individuals can be better estimated, providing risk communicators with an improved basis for developing improved communications that elicit the desired responses. The remainder of this section elaborates on the four frameworks introduced above and how they may pertain to the hazard-response cycle in the context of risk communication.

2.2.4.1 Psychometric Paradigm of Risk

The psychometric paradigm helps to explain how individuals' levels of perceived risk are predominantly a result of affective factors (i.e., emotions, attitudes, feelings, beliefs, and experiences) that a hazard elicits (Slovic et al., 1986). This paradigm argues that there are two affective factors highly involved in influencing risk perceptions: *dread risk* and *unknown risk*. *Dread risk* refers to an individual's perceived catastrophic (i.e., danger) level of the anticipated threat, while *unknown risk* refers to an individual's perceived controllability of their outcomes from their actions and the predictability of the anticipated impacts (Gierlach, 2010). Greater perceived risk is due to a combination of high dread and unknown characteristics (i.e., lack of control) surrounding a threat and its impacts (Slovic and Weber, 2002). Slovic (1987) summarized these findings by creating a two-factor space chart with *dread risk* on the horizontal and *unknown risk* on the vertical axis, where lay people's risk perceptions of hazards are positioned accordingly (see Figure 4). The thinking behind this is that the further to the right that a hazard falls within the 'factor space' the more likely that the lay public would respond to the risk and advocate for risk-mitigating interventions (Slovic, 1987; Morgan et al., 2002).

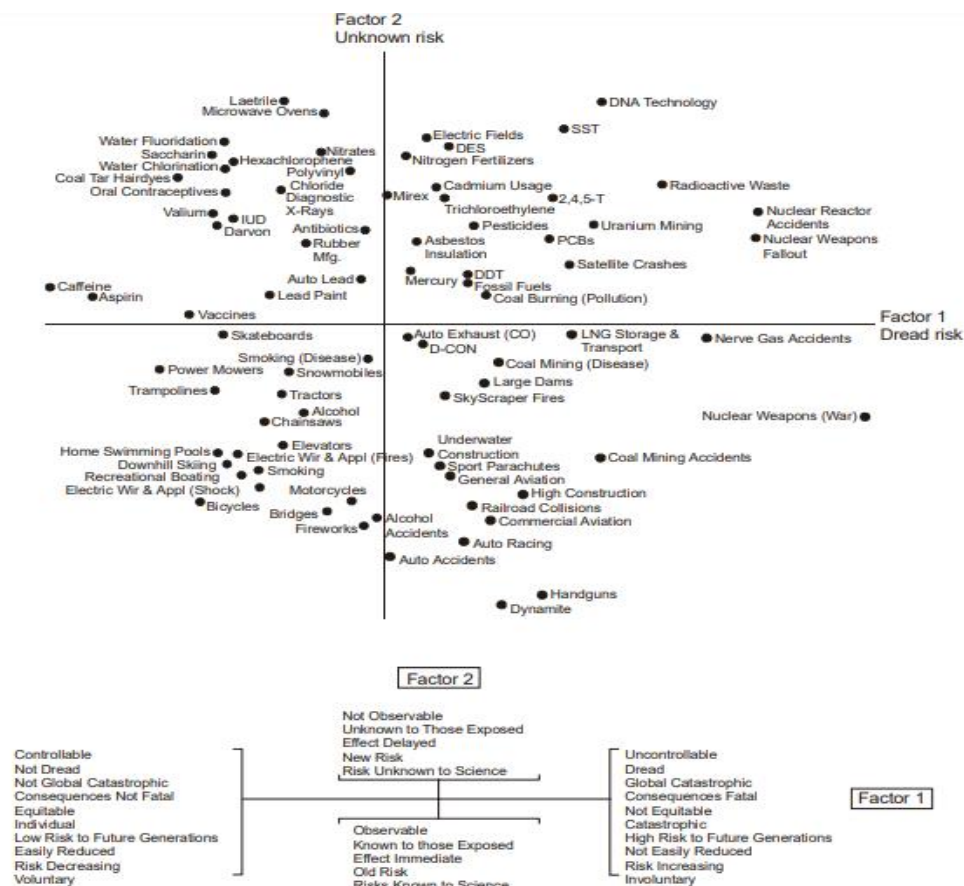


Figure 4. Two-factor space of dread and unknown risk for several different hazards (Slovic, 1987).

Later work addressed another consideration, that of exposure, leading to a three-factor space (*dread risk*, *unknown risk*, and *exposure*) (see Slovic et al., 1987). Despite the scholarly enhancement, subsequent empirical findings corroborated the inability of the framework to adequately predict or explain behavioural outcomes under risk; instead, the model's primary use is in quantifying risk perceptions and how they are formed and change (Wachinger et al., 2013; Lechowska, 2018; Anderson et al., 2023).

2.2.4.2 Social Amplification of Risk Framework

The Social Amplification of Risk Framework (SARF) was an explicit attempt at combining psychometric and cultural-social research into a framework of relationships that influence risk perceptions in the context of the risk communication chain (Pidgeon et al., 2003; Kaspersen et al., 2022). In practice, the SARF was created to understand the role of risk communication media sources on risk perceptions and better understand why responses differed

between groups during the same risk event (Kasperson et al., 2022). Similar to the psychometric paradigm of risk, the SARF proposes that risk amplification occurs when the public perceives hazards as a higher threat than objective technical analysts purport; conversely, risk attenuation occurs when the public underestimates risks that technical analysts have otherwise objectively perceived as a higher threat (Kasperson et al., 2022). The SARF posits that the observed differences in risk perceptions start from initial ‘risk signals’—the communication of risk information about an event through various direct and/or indirect media sources (i.e., official alerts, media reports, social networks) (Kasperson et al., 2022). The amplification or attenuation of these risks is enabled via *amplification stations* (e.g., social media, cultural and personal beliefs and experiences, direct conversations, traditional media – radio, television), where psychological and cultural-social processes shape subjective risk perceptions and responses to the hazard (Kasperson et al., 2022). Processes that have been given considerable empirical focus include trust, emotions, social comparisons, stigma, and other cognitive biases (Kasperson et al., 2022).

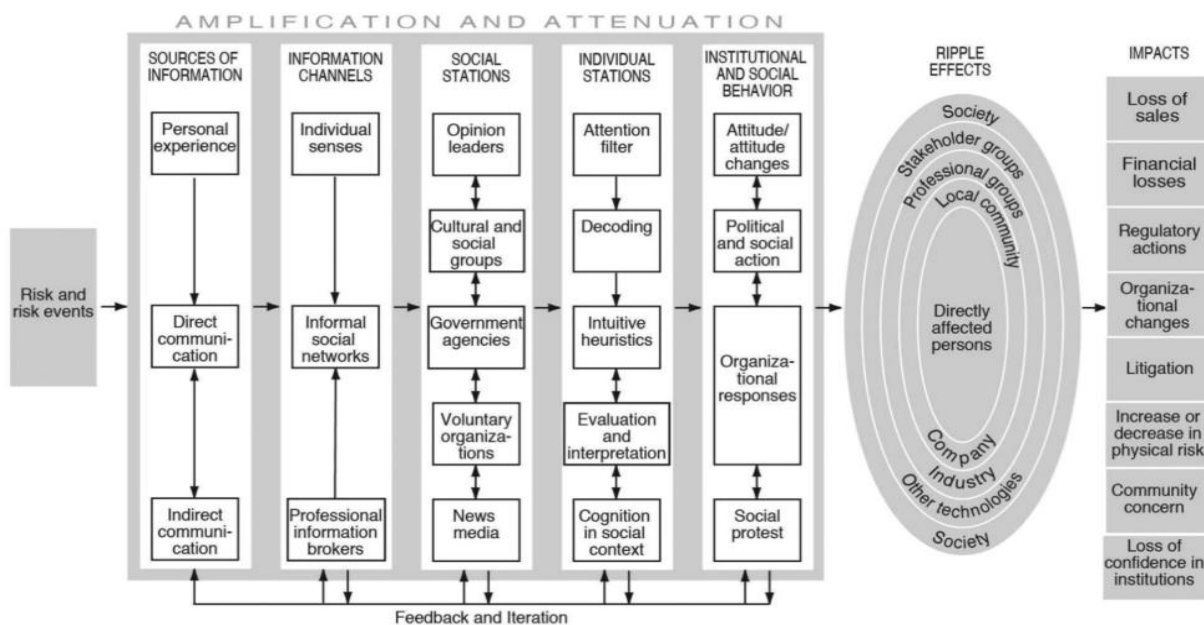


Figure 5. The Social Amplification of Risk Framework (Kasperson et al., 2022).

The SARF remains one of the most popular conceptual frameworks for interpreting social dimensions of risk and has been employed in several different risk communication contexts (Kasperson et al., 2022). Recently, the principles of the SARF have shown how technological advances can affect risk perceptions; these connections are being used extensively in social

media studies, where different messages and their effects on risk perceptions are being explored (e.g., Fjaeren and Aven, 2021). For example, Binder et al., (2014) examined how news media can play a role in the social amplification of risk through distorted risk signals and the use of fear-inducing messages. Overall, the SARF provides a seminal framework that is used for understanding how the lay public's perceived risk is amplified or attenuated through different sources of risk information.

2.2.4.3 The Protective Action Decision Model

The Protective Action Decision Model (PADM) introduced by Lindell and Perry (2012) is a relatively recent theoretical framework that at its core, is an attempt to understand the role that various influential factors have on individuals' protective action decision-making across varying hazards and spatio-temporal contexts. The PADM has since begun preliminary use in the risk communication and emergency management sectors as an aid in the testing and delivery of increasingly effective risk messages that motivate protective actions by testing the role of several influential variables in a sequential process (Heath et al., 2018). The model indicates that an individual's decision to take action regarding a hazardous threat is dependent on a sequential multidimensional decision-making process with four distinct stages (See Figure 6):

- Stage 1 emphasizes the role of pre-decisional processes, i.e., exposure, attention, and comprehension of hazard information communicated through social and environmental cues, as well as official risk messages, in motivating response (Lindell & Perry, 2012). These pre-decisional processes must occur before stage 2 where risk perceptions are formed and stage 3 where decision-making occurs.
- Stage 2 emphasizes the role of three interacting perceptions. The first is risk perceptions regarding the threat, which consists of two components; probability of occurrence and severity of impacts. The second is perceptions regarding protective actions, which consist of self-efficacy and response efficacy. The last is the perceptions of stakeholders, which consist of trust, responsibility, and competence.
- Stage 3 is where protective action decision-making occurs. Protective actions in this model are an outcome of the interdependent and causal interactions of variables in previous stages.

- Stage 4 is the final stage at which behavioural responses occur as outcomes of the protective action decision-making responses, as well as any situational factors that impede or promote one's ability to carry out protective actions. Responses in the model include protective action responses, further information searching, and emotion-focused coping.

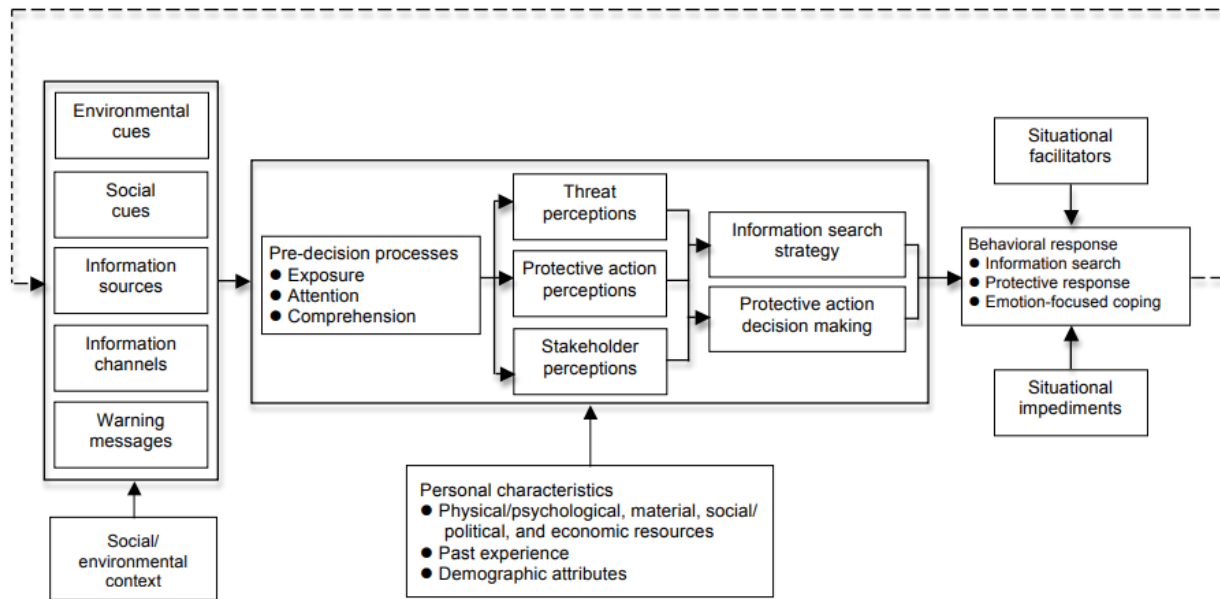


Figure 6. The Protective Action Decision Model (Lindell, 2018).

Unlike the Psychometric Paradigm and SARF, the PADM posits that attention, as well as risk perceptions, are both critical aspects of protective action, with the former being a key predictor of risk perceptions (Lindell and Perry, 2012). The PADM focuses on information received from the environment, risk agencies, and social observation of others to increase attention to hazards and motivate people to take protective actions (Lindell and Perry, 2012). Understanding of the power of these sources in eliciting this attention and the pathways of influence leading to protective actions has been understudied and thus lacks sound empirical support (Silver, 2017, 2019). This is surprising given that attention (as well as time) is noted by Morgan et al. (2002) as a principal obstacle to laypersons' understanding of risk(s) and protective actions. Recently, Lindell (2018) addressed the influential role that several personal characteristics may have on the core cognitive factors in stages one, two, and three; which could aid in the understanding of the observed relationships. Though, Lindell (2018) notes the need for

further empirical insights into the influential role, and the relative importance, of these proposed characteristics and others on the pathways of influence to protective actions. Attentiveness to information may be a key characteristic to understanding why some individuals take protective action, while others do not. This model is a good basis for the proposed thesis study as it focuses on the processing of information derived from both social and environmental cues (Lindell and Perry, 2012), and the main sequential pathways of influence to protective actions, similar to the ‘model of attention creation’ developed by Silver (2017).

2.2.4.4 Model of Attention Creation During Extreme Events

The model of attention creation during extreme events is a representation of how public attention to environmental hazards is created (Silver 2017, 2019). The conceptual model shows how attention is a ‘process created across space and time in response to an individual's exposure to an extreme event and their following interactions with information about the event’ (Silver 2017, 2019). Similar to the SARF and PADM, the model posits that attention begins with passive exposure to external stimuli through direct (i.e., environmental or social cues from others) or vicarious/indirect experiences (i.e., traditional media, social media, word of mouth, or warning messages). Following exposure to risk messages, individuals then notice, focus on, and interpret the information before responding (or not) to the information through risk perceptions, decisions, and protective actions (Silver, 2019) as reflected in Figure 7. One particularly relevant aspect of the model is the concept of interpretation of selected risk information which takes into account sense-making theory (Weick, 2005). Additionally, the ideals of human agency are taken into account, where people actively make sense of their information within their situational contexts and take actions to alter their outcomes to meet goals and desires (Bandura, 2012). The model posits that attention to relevant information increases in response to several factors: information has to be personally relevant, understandable, salient (i.e., it stands out from the rest of the information), and communicates a heightened level of risk (Lindell and Perry, 2012; Silver 2017, 2019). Failure to meet any of these conditions is thought to result in a discontinuation of attention to the information and further processing important for decision-making (Silver, 2019).

Empirical work to date has focused on social media users' interaction with weather information through re-tweets and discussions (Silver and Andrey, 2020; Silver and Behlendorf, 2023). Results from these studies found bias towards engagement by professionals and weather

enthusiasts (Silver and Andrey, 2020), providing limited insight into the lay public’s responses. Also, such studies ignore context, as it is not clear what activities people are engaged with when they go through the process of attention creation and response (except perhaps through an exhaustive analysis of photos or ‘naturalistic’ methodologies, such as experience sampling method Mills 2021). Therefore, what has not been tested is attention across time in a realistic scenario. Overall, the model of attention creation during extreme events, much like the PADM lacks empirical support and both call for the need to test other factors that may further explain continued variability in behavioural responses (Lindell and Perry, 2012; Silver 2017, 2019).

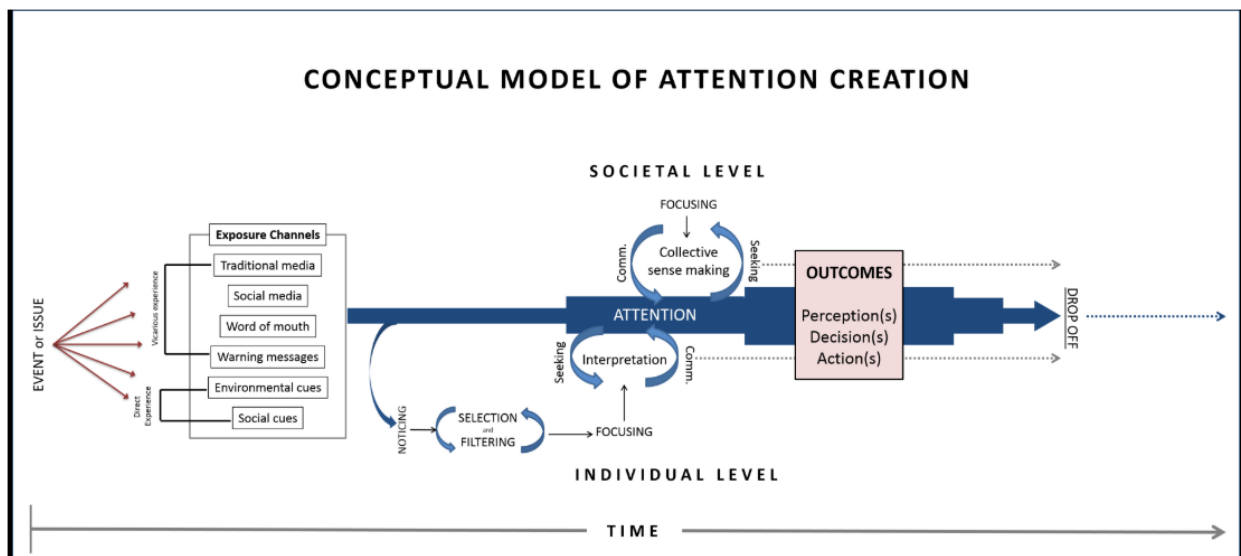


Figure 7. The Conceptual Model of Attention Creation during an extreme event (Silver, 2017).

2.2.5 Empirical Research on Influential Factors on Risk Perceptions, Attention, and Responses

Empirical work that has been conducted to test and evaluate theory and supporting hypotheses has identified several factors that may influence individuals’ risk perceptions, attention, and responses. Common themes include affective (e.g., emotions and feelings, past experiences), cognitive, (e.g., mental models and heuristics), contextual (e.g. risk framing, information sources, and situational factors), and sociodemographic (e.g. personality traits, previous experience, age, gender, culture, etc.) factors. Thus, responses to similar pieces of risk information differ greatly between individuals. Most of the literature has focused on risk perceptions and their influence on behavioural responses in conjunction with the above factors. Surprisingly, empirical works aimed at exploring attention and its influence on risk perceptions and behavioural responses, in conjunction with other influential factors, are lacking in the

environmental hazard literature, though several studies have begun to explore the relationships, showcasing growth in this area (Carlson et al., 2019; Mrkva et al., 2021; Silver 2017, 2019). Given the growing list of factors thought to influence decision-making that are not explicitly described in the four models considered, it is prudent to cover the existing literature on the topic in relation to environmental hazards in the context of risk communication. The following sections explore the influence of several notable factors, highlighting links between risk perceptions, attention, and behavioural responses wherever possible. For further insight into how various individual human factors, referred to as receiver characteristics in the remainder of this thesis, influence risk perceptions and responses to environmental hazards, there are several reviews available (e.g., Sorensen, 1999; Morrow, 2009; Bubeck et al., 2012; Fischhoff, 2013; Lechowska, 2018; Siegest and Arvai, 2020; Morelli et al., 2022; Anderson et al., 2023).

2.2.5.1 Socio-Demographic Characteristics

Socio-demographic characteristics have been influential, to varying degrees, on individuals' risk perceptions, attention, and responses to environmental hazards (Siegrist, 2000; Wachinger et al., 2013; Sherman-Morris, 2013; Silver, 2017). Some of the most studied variables include gender, income, education, residency/locality, age, ethnicity, and culture (Savage, 1993; Sorensen, 2000; Gierlach. 2010; Casteel and Downing, 2013; Silver and Andrey, 2014). Regarding the influence of gender, most studies have found that women generally express higher perceived risk than men (Wachinger et al., 2013) and are more likely to take protective actions (Sherman-Morris, 2005). These findings suggest an explanation for observations of higher hazardous event casualties in men over women (e.g., lightning Mills, 2008, 2020, tornadoes Sherman-Morris, 2005). Greater household income and the completion of secondary school have also been shown to amplify risk perceptions and related protective actions in a way that leads to fewer casualties (Schmidlin et al., 2009). Further, locality plays an influential role in risk perceptions and responses in complex ways (Stewart et al., 2012; Silver and Andrey, 2015). For example, in a nationwide study of the United States, Stewart et al. (2012) found that individuals who reside in climates with higher frequency of certain hazardous events (e.g., tornadoes) and variability in weather patterns, express increased 'salience', risk perceptions, and protective actions in response to hazards compared to those residing in different climates, differing in the frequency and severity of similar hazards. Little research has been done linking attention to

socio-demographics, though Silver and Behlendorf (2023) found that people who engaged with weather information during Hurricane Dorian were younger (less than 40 years old) and were more likely to report protective action decisions than were older adults who were less attentive to weather information.

2.2.5.2 Weather Knowledge

While the empirical literature surrounding the influence of weather knowledge on thunderstorm responses is limited, some studies provide initial insights. For example, studies have shown that the lack of knowledge about weather terminology among recipients, such as the difference between tornado watches and warnings, leads to less protective action uptake (Donner et al., 2012; Walters et al., 2020). Another study found that respondents with lower weather knowledge were more likely to overestimate their actual knowledge and preparedness levels and were less likely to take protective actions when presented with a simulated tornado situation (Casteel, 2023).

2.2.5.3 Previous Hazard Experience

Individuals with varying hazard experiences, either directly or indirectly, have been shown to respond differently to hazard information in important ways (Benight et al., 2007; Silver and Andrey, 2014; Drost et al. 2016; Demuth et al., 2016; Armstrong and Usery, 2022). This is intuitive, given that experiences and associations in the context of processing risk have always been the basis of threat detections for humans. These experiential responses to threats link experiences to emotions and affect (feeling that something is good or bad). As a result, uncertain and threatening aspects in an environment transform into affective responses (e.g., fear and dread), representing a relatively new concept, *risk as feelings* (Loewenstein et al., 2001; Slovic and Weber, 2002). Recent research by Morss et al. (2018) tested the effects of fear-based messages on decisions; results support the notion that fear and worry surrounding the risk of impacts from severe thunderstorms are influential. Other research indicates the importance of initial views of risk information, whereas strong initial views are resistant to change due to a high influence on the interpretations of subsequent information (Slovic, 1986, 1987).

The effects of previous hazard experience(s) on protective action (i.e., shelter-seeking) tendencies are not always found to be consistent in the literature. Comstock and Mallonee (2005) and Murphy et al. (2005) found that individuals who had experienced a destructive tornado were

more likely to take protective action given adequate shelter and warnings in the future. These findings may be in part due to the *availability heuristic* (Tversky and Kahneman, 1973). The *availability heuristic* implies that individuals perceive future events as being more likely if examples of the event and its negative impacts are recalled easily from memory (Gierlach, 2010). This contradicts other research on tornadoes, such as the findings by Silver and Andrey (2014), that show that almost half of the individuals in Goderich, Ontario who were directly and indirectly affected by a destructive EF3 tornado in the town did not take protective action three days later when a similar tornado warning was issued.

2.2.5.4 Environmental Cues

Existing literature shows that successful risk perceptions, depend, in part, upon how individuals gauge risk(s) from observable cues in their surrounding environment (Lindell and Perry, 2012; Silver, 2012; Brotzge and Donner, 2013; Dewitt et al., 2015). When gauging one's level of risk, individuals explore their surrounding environment and related hazard cues in tandem with the other information they have received, such as official risk information (i.e., severe thunderstorm watches and warnings) to inform their decisions (Lindell and Perry, 2012). An individual's ability to evaluate the meaning behind environmental cues and their surrounding environment is critical because forecasts are imperfect and thunderstorm hazards, especially lightning, may strike without any official warnings (Dewitt et al., 2015). This ability is an essential part of an individual's protective action decision-making that gives them an incentive to seek shelter or not (Lindell and Perry, 2012). While accurate assessments of the meaning behind environmental cues has been shown to be an important part of an individual's decision-making process (Lindell and Perry, 2012), success in taking shelter has been shown to be rooted in one's ability to assess their level of associated risk (Sutton et al., 2021). While some individuals may still be more risk-adverse (i.e., less likely to take protective actions), the ability to be attentive to thunderstorm cues as a prerequisite to the undertaking of accurate interpretations of hazard information may prevent some future casualties.

For some natural hazards, the presence of environmental cues may elicit stronger behavioural responses than officially communicated information. For example, during the 9.0 earthquake and subsequent tsunami in Japan in 2011, villages that suffered the least number of casualties from the tsunami, despite their villages being destroyed, fared well because of their

knowledge about the advantage of going up nearby hills following the environmental cue of a large earthquake, rather than relying on coastline tsunami infrastructure or official instructions (Muir-Wood, 2016). Finally, using focused interviews and questionnaires, Silver (2012), found that the factor most associated with protective actions from a destructive tornado were environmental cues (i.e., unusual or threatening conditions, associated with intense, wind, rain, or hail). These findings are unsurprising given that many researchers have posited that most people seek to confirm warning messages, especially for atmospheric hazards, with personal observations and/or other information before responding (Dewitt et al., 2015).

2.2.5.5 Situational Factors

Hazard mitigation and risk reduction literature, from a mainly theoretical basis, expresses that situational factors may influence individuals' attention, perceived risks, and behavioural responses to hazards (Lindell and Perry, 2012). Recent empirical literature supporting these claims has shown that limited access to adequate shelter, activity importance, and mobility constraints are the most important situational factors acting to impede protective action responses (Lindell and Perry, 2012; Weyrich, 2020a; Woods, 2021). For example, a study comprising of a simulated evolving thunderstorm threat over the course of a large outdoor event found that when participants had to pay to attend an event, they were more likely to delay their protective actions until the thunderstorm threat was most imminent (Woods, 2021).

2.2.5.6 Attention

Public attention in relation to environmental hazards is defined by Silver (2019: 301) as, "...the process of noticing, selecting, and focusing on one or more external stimuli (e.g., hazardous event or event-related information) to which people are exposed." Given the relatively recent conceptualization of attention in the realm of environmental hazards (see section 2.2.4.4), attention and its role in the hazard-response cycle for environmental hazards has received little empirical investigation. Empirical studies treating attention within the hazard-response cycle for environmental hazards have demonstrated that it is an influential factor in risk perceptions and subsequent decision-making (not necessarily protective-action) responses (Newig, 2004; Lindell and Perry, 2012; Ripberger et al., 2014; Silver, 2017; 2019). Although attention to weather information and environmental cues have been hypothesized to influence whether or not individuals take protective actions (Lindell and Perry, 2012; Ripberger et al., 2014; Silver, 2017;

2019), this has not been confirmed through empirical studies. This may be due to methods that mostly measure iterative processes, such as information-seeking and sense-making. Attention has been shown to influence risk perceptions (Mrkva et al., 2021), a connection stated initially by Newig (2004: 154) whereby attention “...does not indicate what people think about, but what they think about it.” Three questions emerge from the research on public attention to environmental hazards: (1) at what point does something gain someone’s attention? (2) Why do some people pay attention to environmental and social cues, as well as official sources of weather information more than others? And, (3) does attention lead to protective actions, and if so, at what point?

2.2.5.7 Other Influential Characteristics

Synthesizing the above literature on risk perceptions, attention, responses, and the links between them through an exhaustive review of the theoretical and empirical literature, it is clear that individuals pay attention to, perceive, and respond to risk information in differing and complex ways (Sutton, 2023). Despite the decades of empirical and theoretical contributions translated into robust risk communication and management systems, distorted perceptions of risk and other factors between experts and members of the public continue to lead to satisfactory, rather than optimal outcomes (Wilson et al., 2019; Anderson et al., 2023). This has been demonstrated through the results of empirical studies that found weak causal relationships between risk perceptions and protective action behaviours (Anderson et al., 2023). As such, one critical question remains: why do some individuals respond differently to identical weather information and situational characteristics despite similar degrees of risk perceptions, attention, and socio-demographic characteristics?

Other attempts to determine differences in these interactions have recently focused on understanding individuals’ inherent characteristics, personality trait-like features, or “ways of being” that are both independent of exogenous events, situational and other individual characteristics, and also influenced by them (Stewart, 2009; Bolton, 2022; Bolton and Lazzaro, 2022; Armstrong and Usery, 2023). More specifically, general constructs that are foundational to everyday thoughts and actions, vary between individuals, and are exogenously relatively stable outside of specific situations and thus can be reliably tested across different populations and events. The underlying assumption of research in this area is that the degree of influence from

these constructs towards general experiences reflects foundational cognitive dispositions that are more reliable than characteristics that depend more on and fluctuate according to exogenous factors (Jensen et al., 2016).

The need to understand the role that trait-like characteristics played in the hazard-response cycle for environmental weather hazards led to the creation of the concept of weather salience (Stewart, 2009), which is defined as, “the psychological value, significance, and attunement that people have for the weather and its changes.” (Stewart, 2009). Weather salience proposes that understanding differing perceptions of and responses to weather hazards lay in differences between people’s inherent levels of psychological significance they placed on the weather (Stewart, 2009). Synthesizing the existing literature on weather salience, it has been shown that weather salience is an influential factor in attending to, perceiving, and understanding weather information and environmental cues (Stewart, 2009, Ripberger et al., 2014; Silver, 2014; Dewitt et al., 2015; Potter et al., 2018). A large study done on the population of the United States confirmed the existence of the weather salience concept and that high weather salience correlated with living in climate zones that experienced more weather changes, higher tolerance for weather changes, and usage of weather products for information (Stewart, 2012). A Canadian study found that greater weather salience influenced the frequency at which people accessed information about the weather through various media sources (Silver, 2012). Relatively recently, Stewart’s seminal work on people’s inherent traits in relation to the weather has advanced—mostly through critical introspection and additional theoretical contributions (See Bolton, 2021, 2022). For example, Bolton (2022), criticized the original weather salience concept for its surface-level and general understanding of people’s psychological attunement to the weather, proposing the need for an understanding of other individual-level trait differences (Bolton, 2022). Differences in individuals’ inherent traits have since been noted as possible explanations to differing perspectives of the weather between experts and the lay public (Stewart et al., 2012, 2015, 2018; Spinney, 2014; Williams et al., 2017; Bolton et al., 2020, 2022).

Recent work related to the original weather salience concept has built on Stewart’s work with the aims of gaining a greater understanding as to why particular aspects of the weather are more salient than others based on additional inherent personality-type traits, including weather curiosity (Stewart, 2017; Bolton et al., 2022), anxiety and phobias (Bolton, 2022), systemizing, (Bolton et al., 2018), sensitivity (Bolton, 2021), and weather-connectedness (Vet, 2017), a

concept furthered by Bolton, (2022) as the need for cognition about the weather- “a general interest in learning about weather and curiosity for the science behind the weather” (pp. 1). While these inherent individual-level trait-like features have been tested and have helped lead somewhat to a better understanding of the connections between weather information and responses (e.g., storm phobias and fears lead to constant monitoring of weather media and avoidance of weather-related exposure possibilities as noted by Coleman et al., 2014 and Bolton, 2021 or individuals expressing the personality traits of agreeableness and conscientiousness were more likely to take protective actions through preventative coping to weather hazards as noted by Prochniak and Prochniak, 2021), other trait-like features that may help further this critical gap have lacked theoretical conceptualization and empirical investigation in the realm of environmental hazards. As such, social scientists within the realm of environmental hazards have continually advocated for the operationalization of other concepts that integrate theory existing outside of the environmental hazard’s literature (Silver 2017; Weyrich, 2020a). It is also beneficial to incorporate theoretical models into risk communication research in that any connections between information, factors, and behaviours predicted hypothetically from the model in comparison with empirical findings provide greater predictability towards how actual changes in communication practices will elicit intended responses (Demeritt and Nobert, 2014).

2.2.6 The Need for the Operationalization of Attentiveness in Weather Risk Communication: Weather Attentiveness

One concept that may be particularly important in understanding responses to risk information is attentiveness, a cognitive-based concept used in other fields as an independent predictor of adaptive responses to changing environments. For example, Rueda et al. (2021) argued that attentiveness, in combination with internal motivations, goals, and past experiences, is a critical aspect in eliciting responses to one’s environment. They defined attentiveness as, “... a state of optimal activation that allows selecting the sources of information and courses of action in order to optimize our interaction with the environment in accordance with the saliency of the stimulation or internal goals and intentions.” (Rueda et al., 2021: 1). Attentiveness is considered synonymous with active empathetic listening; ‘involving one’s ability to pick up on relational contexts of information pertaining to situations through actively sensing, reflecting on, and then responding in a meaningful way during inter-personal communications (Edwards, 2011;

Bodie, 2011). While differing views of attentiveness exist in the literature, a synthesis of the common themes leads to the following preliminary operationalized definition in relation to the weather:

Weather attentiveness is the ongoing process of an individual actively seeking, perceiving, interpreting, and engaging with information about the weather that is meaningful to their weather-relevant goals.

Synthesizing the attentiveness literature, several important aspects of the process are apparent: (1) it reflects someone's concentration and engagement with an event, (2) it is relational, in that people apply particular meaning to events based on the attentive "lens" which they are using, (3) it is influenced by affective mechanisms (i.e., emotions and mental shortcuts), (4) it is an active process, containing both automatic, intuitive responses, as well as reflective, more thought-out responses, (5) it is influenced by the saliency and accessibility of stimuli surrounding an event, (6) it is goal-oriented, reflective of one's internal objectives, (7) is an inherent trait-like quality, differing from person-to-person in absence of external factors, and (8) affects behaviours (Norton and Pettegrew, 1979; Coker, 1981; Reynolds 2008).

Taking an agentic perspective, this thesis posits, similar to other views of attentiveness (e.g., moral attentiveness Reynolds 2008) that weather attentiveness is both an intrinsic trait, varying between individuals in the absence of external factors, but also influenced by them during specific events. Attentiveness is different from a more recently conceptualized intrinsic trait of human-weather interactions, the concept of epistemic (information-driven) weather curiosity proposed by Bolton et al. (2022). Weather curiosity reflects people's general need to know more about the weather and the science behind its workings (Bolton et al., 2022). In contrast, weather attentiveness reflects people's tendency to perceive information and external stimuli as weather-relevant, based on their internal goals and desired outcomes (e.g., making decisions to continue outdoor activities as thunderstorms form and/or approach). Therefore, as curiosity reflects more of a general inclination to understand the weather, attentiveness is more goal-oriented, in such a way as to make better decisions based on informational and environmental cues.

Similar to Reynolds' (2008) concept of moral attentiveness, which provides a way to predict why some people react differently to similar moral issues, weather attentiveness may provide insights into why some individuals respond differently to similar weather conditions; a connection not explicitly found through the learning-based weather curiosity construct (Bolton et al., 2022). While weather curiosity implies an intrinsic desire to learn about the weather, weather attentiveness implies continually monitoring changing weather conditions through a weather-related "lens" to inform weather-related decision-making. Weather attentiveness involves both perceptual, automatic responses in which information is screened when encountered through the lens of weather-relatedness and, slower, reflective thinking and responding, taking into account previous understanding of the weather information based on relevant past experiences, knowledge, and constant attending to weather-relevant information in daily occurrences. Due to the frequent reflection of weather-related information in the lives of people who express greater levels of weather attentiveness, it can be argued that they will pay more attention to and respond in environments with weather-relevant stimuli or "cues" than those less weather attentive (Woods et al., 2021). Spinney (2014) implicitly uncovered this understanding of weather attentiveness through observing meteorologists' interactions with weather outside of the organizational office; where they constantly noticed changes in their external environments through a meteorological lens. Meteorologists, as she argued "live and breathe the weather", by such responses as monitoring clouds at baseball games to discern thunderstorm potential or by labelling weather as 'risky' or 'non-risky' based on their monitoring of environmental cues and their interactions with weather media (Spinney, 2014: 42).

Recognizing a weather event as an intolerable risk is required for protective action-decision making (Wachinger et al., 2013; Anderson et al., 2023). This outcome requires someone to be aware of weather risks, sensitive to recognizing the weather risks when exposed to them, and attentive to the weather risks that do arise. Awareness is simply to know that weather risks are possible when outdoors. Sensitivity takes the weather-relevant cues that someone is inherently aware of and 'tags' those cues in the environment, while attentiveness recognizes the 'tagged' cues as relevant to their internal goal of maintaining safety and then makes decisions based on their relevant risk. For example, someone's internal goal of keeping safe while on a hike entail being attentive to the changing clouds in the environment and weather information while hiking outdoors that is relevant to their safety. As such, weather attentiveness can be

thought of as an active process of both paying attention to and responding to weather-relevant information in a meaningful manner associated with desired goals (Norton and Pettegrew, 1979; Coker, 1983). This is different from the concept of public attention in relation to environmental hazards as defined earlier as a primarily reactive process beginning with the passive exposure to cues from a risk event (Silver, 2017, 2019). In essence, weather attentiveness optimizes one's likelihood to pick up on attentional "signals" related to the weather and needed behavioural adjustments in one's environment.

2.2.6.1 Measuring Weather Attentiveness

Attentiveness cannot be directly observed or measured because it is a psychological construct. Lovasz and Slaney (2013: 6) define psychological constructs as, "real but potentially unobservable structures, mechanisms, and processes that might play a mediating role in stimulus-response relationships." As a result, attentiveness is measured by observing the behavioural "signals" indicative of its occurrence according to theoretical associations of the construct (Lovasz and Slaney, 2013). As Norton and Pettegrew state (1979: 1), "a person is attentive to something when their energies and activities are directed towards it." Coker, (1981) expressed that the common behavioural outcomes thought to indicate one's attentiveness in behavioural interactions included: body movements (e.g., head nodding, leaning forward, smiling, and eye contact) and use of relational language (e.g., encouraging one to talk by relating similar experiences) or phrases (e.g., restating what the other person said) that people used to demonstrate to another that they are attentive to them (Norton and Pettegrew, 1979, Coker, 1981). When someone is attentive to the weather, their behaviours indicate that they are fully involved with the information about it in an active and responsive manner. These behaviours are myriad and would theoretically involve someone's active search for information about the weather through weather communication mediums, and their continued observation of weather changes, such as clouds or audible cues of thunder. Therefore, attentiveness is measured by assessing the frequency or degree to which someone is actively interacting with information about the weather, through communication mediums, by monitoring changes in the weather in a particular environment, or as the likelihood that weather information or environmental cues enact their continued attention. This is different from someone's awareness, which is simply to know that the weather can change or that they can use weather communication mediums to access

information about the weather (Silver, 2017). The relative strength of these “signals” concerning changes in weather conditions could arguably showcase how people’s attentiveness changes with evolving weather conditions.

2.2.6.2 Influences on Attentiveness

Attentiveness may be influenced by personal interests, the personal relevance to one’s situation and/or environment, the affective-responses it invokes, as well as the saliency and accessibility of the information (Fiske and Taylor, 2017). Interest, personal relevance, situational characteristics and affective-response factors were discussed previously, thus only saliency and accessibility will be further covered in this section of the literature review.

Salience affects individuals' attention to a stimulus (Fiske and Taylor, 2017). Salience is a psychological response referred to as the “propensity” for something to stand out in someone’s environment (Fiske and Taylor, 2017). Here the focus is on perceptual salience - a cognitive bias that causes individuals to focus on external stimuli that are more visible, prominent, audibly different, or emotionally striking than other objects in their environment (Schenk, 2011). Salience has been shown to contribute to increased attention towards something because the stimulus ‘sticks’ out from the rest of the objects in a landscape, causing someone to direct their attention towards it (Kruger et al., 2017). Saliency is improved through associations with stimuli, which can be strengthened by relevant past experiences (Fiske and Taylor, 2017). The understanding of a stimulus due to associations creates what is referred to as the *Cocktail Party Effect* (Cherry, 1953). For example, a person recognizes their name being called at a busy conference despite many competing sounds due to the personal association and understanding of a particular sound being their name. It is important to note though, that the motivating factors for selecting a stimulus are not always physical factors (e.g., intensity, clarity, size, colour); emotional, motivational, or other cognitive factors may also make a stimulus more salient (Tsakanikos, 2004). As such, researchers have concluded that the saliency of stimuli are, in part, strengthened by associations with stimuli, with further influence from relevant past experiences and the physical and emotional effect they might have had (Kahneman, 2011). The ease of recall about information regarding the stimuli acts as a mediator in this process (Fiske and Taylor, 2017).

As such, an individual who is considered weather salient may more readily notice changing sky conditions, such as the building of thunderstorm clouds (i.e., cumulonimbus) (Dewitt et al., 2015). This is because the large and billowing thunderstorm clouds of a cumulonimbus stand out when contrasted with the visual landscape of a clear and blue sky or a sky with several smaller (i.e., cumulus) clouds; as would the presence of audible thunder in an otherwise quiet environment. The combination of these visual and audibly salient stimuli create what Dolan et al. (2012) refers to as a *saliency bias*. This bias is further enhanced by familiarity with a stimulus (Dolan et al., 2012). This is supported by studies showcasing that formal training (i.e., through ‘storm spotter’ workshops facilitated by meteorological organizations) of the visual cues associated with thunderstorms increase the perceptual saliency of the cues (Dewitt et al., 2015), though storm spotters can at times have difficulty distinguishing between complex features of thunderstorms that may indicate the possibility of tornadoes (i.e., wall clouds) or straight-line winds (e.g., shelf clouds) (Brotzge and Donner, 2013). Given that the saliency of stimuli are affected by extreme or unusual aspects of them (Einhauser et al., 2024), rare risk message characteristics, such as wireless emergency alerts may lead to an increase in attentiveness to the weather.

2.2.6.3 Framing Weather Attentiveness in the Hazard-Response Cycle

To gain a better understanding of what weather attentiveness is, what factors may influence it, how it may differ from person-to-person, and how it may influence decisions, this thesis draws from social cognitive theory to provide operationalization and conceptualization of this construct in the environmental hazard’s literature. Social cognitive theory has been used to develop similar measures in other fields of study (e.g., the construct of moral attentiveness Reynolds, 2008). Social cognitive theory was developed by Albert Bandura to understand the dynamic interactions between people’s internal factors, their environment, and their behaviours (Bandura, 1986). The theory has been used as a theoretical basis for risk communication studies within the environmental hazards literature because of its applicability to individual agency (Bandura, 2001). A more recent example is in studies of public attention to extreme weather events (Silver, 2017, 2019, 2020), which used SCT as a theoretical basis to explain how attention is created from exposure to extreme event information and how it influences risk perceptions and decision-making. Other examples include: disaster preparedness (Paton, 2003; Espina and Teng-

Calleja, 2015; Kitagawa, 2021; Cai et al., 2023; Davarani, 2023), and information-seeking (Li, 2015). Integrations of the theory into environmental hazards literature began with Paton's (2003) social-cognitive preparation model, which took into account inherent cognitive processes underpinning behaviours, to explain why people risk perceptions did not always align with preparedness for environmental hazards. SCT posits that behaviours are a result of individual characteristics, external stimuli, and the interactions between them (Bandura, 1986, 2012; Fiske and Taylor, 2017). It therefore serves as a theoretical framework to understand how individual characteristics in relation to the weather interact (e.g., attentiveness, risk perceptions, knowledge, socio-demographic characteristics) with weather information and how these interactions lead to protective actions behaviours, or lack thereof over time. As applied to environmental risk communication, an incorporation of SCT into a conceptual framework aims to advance understanding into what characteristics lead to greater interactions with risk communication, and in-turn how these influence protective action behaviours. Using the SCT as a foundational basis a conceptual model was created from the literature on the influential factors in the hazard-response cycle for atmospheric environmental hazards, adding in the potential role of weather attentiveness to build on the attempts to predict protective actions in response to hazardous events in the social sciences (Figure 2). Outcomes of respective findings allow for evidence-based integrations into weather risk communications, ultimately increasing uptake by end-users that translates into timely and effective protective actions. This also meets the call for additional works in the field of risk communication of environmental hazards that demonstrate interdependent relationships among explanatory variables and the role of moderating or mediating variables on relationships to dependent variables, as well as adding novel variables into research concerning social and environmental factors affecting the decision of short-notice and high-risk atmospheric hazards (Ejeta et al., 2015).

2.2.6.4 Weather Attentiveness and Protective Actions

Relationships between attentiveness and protective actions have been implicitly found in several empirical studies and psychological observations of human-weather interactions. For example, Silver and Andrey (2015) found that people who check the weather more frequently expressed an increased willingness to cancel plans requiring travel if severe weather warning alerts were issued. Given that people more inclined to feel weather-connected are more likely to

respond to the weather and adjust responses accordingly (de Vet and Head, 2020), people regularly involved with the weather may express similar actions, such as those who seek natural connections (i.e., camping and hiking). One particularly relevant area of study in regards to weather attentiveness may pertain to thunderstorms and outdoor recreational activities given their quick onset and evolution and the necessity for people to remain attentive to their various environmental and informational cues.

2.3 Overview of Thunderstorm Risk Messaging

Risk messages are important in eliciting effective responses for quick-onset thunderstorm events due to the minimal timing between thunderstorm formation and the onset of hazardous impacts that hinder organized responses. Research in risk communication concludes that information that is timely (Durage et al., 2014), understandable (Coppola and Maloney, 2009), consistent (Morrow, 2009), trustworthy (Kox and Thieken, 2017), provides locally relevant information through geographical context (i.e., storm motion and locations to be impacted) (Schumann et al., 2018), and describes the expected impacts and relevant protective actions needed (Potter et al., 2018; Weyrich, 2020b) leads to higher perceived risk and protective action behaviours under thunderstorm threats and exposure (Lindell and Perry, 2012; Golding et al., 2019). The effectiveness of these messages has shown improvement as expressed through case studies, and empirical investigations during and post-event (Mills, 2021, Potter et al., 2018; Weyrich, 2020a).

Recent trends in thunderstorm warnings state both the expected impacts from the indicated hazards in a storm, as well as protective actions to mitigate impacts. The inclusion of the latter has been shown to correlate positively with protective action responses (Sutton et al., 2021). Further, the increasing urgency they express has been shown to increase perceived risk and intentions to take protective actions. Importantly, individuals must know what actions are needed to protect one-self in order to do so (Ripberger et al., 2014; Sutton et al., 2021) and are more likely to do so if they receive information, especially warnings, well ahead of the onset of impacts from an event (Comstock and Mallonee, 2005; Durage et al., 2014).

Weather information is disseminated to end-users through communication channels referred to as weather communication media. These media vary in their ability to provide timely and accurate information when in different settings and the main media sources used have

changed over time. Prior to the recent prevalence of the smartphone, television and internet-based media sources were predominant sources of weather information (e.g., Corso, 2007; Lazo et al., 2009; Silver and Conrad, 2010; Demuth et al., 2011). At present internet-based sources are the main media sources of weather information for a majority of the public (Phan et al., 2018; Vos et al., 2018; Mills, 2021), leaving most empirical research before 2015 with a less applicable picture of today's communication media landscape. The most common internet-based sources of weather information include websites, social media, and mobile weather apps (MWAs), the latter of which being the most common (Parker et al., 2018; Armstrong and Usery, 2022). MWAs disseminate up-to-date weather information to end-users, and it is notable that most Canadians (84%) between the ages of 15 to 64 own smartphones according to a 2021 survey (Statistics Canada, 2023a), making MWAs an invaluable and increasingly used resource for weather information. Most MWAs, such as the one provided by Environment Canada (i.e., weatherCAN), include current conditions (i.e., cloudiness, precipitation type, temperature, air quality, humidity, air pressure, ultraviolet radiation index, and wind speeds). MWAs also display any current alerts and provide hourly, daily, and weekly forecasts that display probabilistic information (usually in the form of percentages from 0% to 100%) of expected weather conditions. This is important as previous empirical findings show that consistent and up-to-date weather information remains a highly influential process in the hazard-response cycle by providing updates on changing weather conditions (Morrow, 2009).

While MWAs are the most commonly used weather communication media at the present time (Parker et al., 2018; Armstrong and Usery, 2023), it is important to note that studies have shown differences in demographic uptake of MWA sources (Bryan et al., 2015). Generally, individuals over the age of ~40 tend to rely more on traditional weather medias (i.e., television, radio, and websites), while individuals under the age of 40 tend to rely more on social media and mobile apps (Bryan et al., 2015). Mobile app use may be lower among older adults, interpreted as those 65 years of age or more, because they less often possess smartphones (Statistics Canada, 2023a), tend to be less able to use technology associated with smartphones and relevant mobile apps (Schegg and Stangl, 2017; Bogdan et al., 2024), and are less open to applications of new technologies (Schegg and Stangl, 2017). Further, Wireless Emergency Alerts (WEAs) are only received by end-users through a smartphone cellular device, radio, or television, leaving those without any of these communication media a lack of important weather information. Further,

given the low uptake of the weather radio program in Canada (Silver and Andrey, 2015), cellular devices remain the only source of WEAs while individuals are outdoors away from the vicinity of homes or other buildings (e.g., information centres in outdoor areas). Adding to this, the assessment of preferred weather communication media for those who commonly engage in outdoor recreational activities is lacking in the literature. To address this gap, it is important to investigate the current use of communication media and the demographic makeup of those who engage regularly in outdoor recreational activities. Given that exposure to information is required for an individual to become attentive to an unfolding situation and change their behaviours (Hornik, 2002), an understanding of the communication media landscape of this population is important to risk mitigation in outdoor recreational areas.

2.4 Summary of Key Research Gaps

While severe thunderstorm forecasts, watches and warnings are meant to prevent exposure to severe thunderstorm hazards, research shows complexities between received weather-related risk information and intended responses from end-users (Stewart et al., 2012; Lindell and Perry, 2012; Silver, 2017). Although previous work has found that risk messages related to hazards play an important role in protective action decision-making, there has been little work done on the influence of different types of messages. Some exceptions include work done by (Morss et al., 2016) on hypothetical hurricane messaging, (Gutter et al., 2018; Weyrich, 2020b) on severe thunderstorm warnings, (Sutton et al., 2021; Riel & Miczo, 2024) on tornado warnings, and (Mills, 2021) on winter storm risk information. Adding to this existing gap in the literature, no academic work has been done to test the influence of different types of messaging in Canada, especially for the recently introduced, Alert Ready mobile WEAs that became operational in 2019. Therefore, testing the effectiveness of this messaging and use of WEAs in a Canadian context will contribute to filling an important gap in the literature on the importance and effectiveness of wireless emergency alerts (WEAs). Adding to this, what we currently understand about attentiveness to thunderstorm information in tandem with the influences of other receiver characteristics and sociodemographic characteristics is lacking in the hazard mitigation and risk reduction literature. Therefore, there is a great need to better understand the role that attentiveness plays in the hazard-response cycle, in tandem with thunderstorm information and other potentially influential receiver characteristics. Implications of any initial

empirical insights from this research could aid in the prevention of casualties in those engaged in outdoor recreational activities, which theoretically serve as high exposure points to thunderstorm hazards (Holle et al., 2021). This study will work to address these gaps.

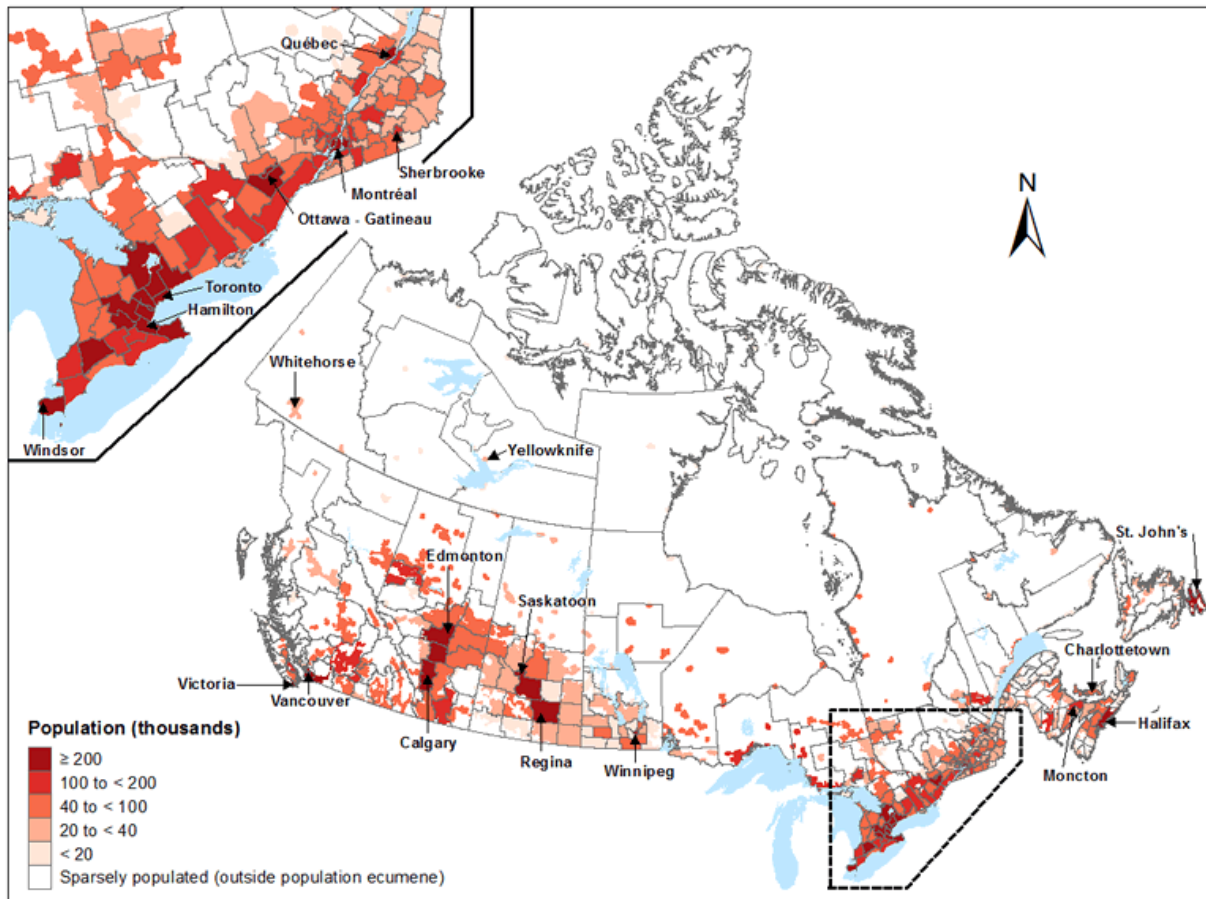
Chapter 3 Study Context and Methods

This study followed a quantitative research design to empirically investigate the influence of weather attentiveness and thunderstorm risk messaging on the recreational activity responses of outdoor recreationists during an evolving thunderstorm event. The specific focus is on thunderstorms in southern Ontario, while camping and hiking. This chapter begins with information about the study area, setting the context for the investigation. This is followed by an overview of the research approach and techniques.

3.1 Spatial Context of Study

3.1.1 Study Area: Southern Ontario

This study focuses on weather attentiveness during warm-weather recreational activities in southern Ontario, Canada. Southern Ontario, the southernmost area of Canada, is located between the Great Lakes, Ontario and Erie to the south and Huron to the west. Southern Ontario has the highest population density in Canada, containing over one-third of Canada's total population, and approximately 94% of Ontario's total population. (Statistics Canada, 2023). Both Canada's capital city of Ottawa, and Canada's most populous city, Toronto, are located in the region, with populations of 6,313,000 and 1,017,449 persons, respectively (Statistics Canada, 2023). The region's population continues to increase, with an almost 7% observed increase in population from 2016 to 2021 (OCC, 2022; Statistics Canada, 2023).



Source: Statistics Canada, Demography Division

Figure 8. 2021 Population of Canada by region, with southern Ontario showcased (Source: Statistics Canada, 2023).

3.1.2 Climate of Southern Ontario

The climate of southern Ontario is considered humid continental with the Great Lakes having a moderating influence on the climate and weather patterns (Sills, 1998, Paixao et al., 2011; Wazneh et al., 2017). In the summer, average daytime high temperatures are between 25°C to 29°C, falling to averages of –6°C to 2°C in the winter³ (ECCC, 2024a). The region is one of the most active areas in Canada for high-impact weather events, and they vary seasonally, including thunderstorms, tornadoes, floods, blizzards, snowsqualls, ice storms, and sometimes, wildfires. Flooding is the most frequent hydro-meteorological hazard that results in high-impact events in southern Ontario (Nirupama et al., 2014). Ice storms, which are long-duration freezing

³ Based off 1991-2021 climate normals.

rain events, produce ice accretion on roads, trees, and powerlines, resulting in hazardous travel conditions, power outages, and falling debris. Ice storms too have resulted in high-impact events, most notably the 1998 Ice Storm, which left millions without power for several weeks and resulted in 35 casualties (CBC, 2018). Blizzards, which are intense and long-duration snowstorms marked by strong winds and heavy snow, result in low visibility and hazardous travel conditions, e.g., the “Great Blizzard of 1978” that resulted in 9 deaths and hundreds of injuries (Burrows et al., 1979). Snow squalls, like blizzards, also are low visibility snow events that typically occur during the late fall and early winter months from colder and dryer air moving over the warmer water of the Great Lakes. Lastly, southern Ontario presents one of the highest thunderstorm and associated tornado risk landscapes in Canada (Etkin et al., 2001; Etkin, 2018; Hury et al., 2016; Kochtubajda and Burrows, 2020).

3.1.3 Severe Thunderstorms in Southern Ontario

Given the high population concentration and frequency of thunderstorms in southern Ontario, it is no surprise that thunderstorm events, and related hazards, especially tornadoes, are some of the region’s costliest and most destructive natural hazards (Cao, 2008; Etkin et al., 2009; Hury et al., 2016). Examples include the 2013 Don Valley flooding event in Toronto, and derecho’s of 1991, 1995, 1998, 2006 and 2022 (CTV, 2022). Tornadoes produced from thunderstorms also have led to several impactful events in recent decades, the tornado outbreak and deadly Barrie tornado of 1985, the 1946 and 1974 deadly tornadoes in Windsor, Ontario, and the record-breaking tornado outbreak of 19 tornadoes in 2009, and Goderich EF3 tornado of 2011 (Morrison et al., 2012; Hury et al, 2016). Though the number of recorded tornadoes has increased in Ontario since the 1970s (Banik et al., 2007), this is in part due to increased populations and widespread use of personal phone equipped with cameras, both of which lead to greater chances of tornado observation. More recently, significant investment in tornado climatology research, principally through the Northern Tornadoes Project (NTP, 2023), and adoption of novel techniques to identify previously unknown tornado tracks (e.g., through analysis of high-resolution satellite imagery) has increased the number of recorded events (NTP, 2022; Kunkel et al., 2023).

3.1.4 Communications About Thunderstorms

Weather agencies, such as Environment and Climate Change Canada, issue relevant information to the public regarding the potential occurrence and severity of hazards (WMO, 2015). Such information generally also communicates the urgency, danger, and actions needed to keep the public safe from the hazard(s). For thunderstorms in particular, this information operates at a temporal scale, from initial forecasts to official watch and warning alerts.

1. Short-term forecasts are provided to end-users several hours to a few days before potential thunderstorm events to convey a general expectation of hazardous conditions across a broad period of the day (e.g., late afternoon). Specific mention of the potential for severe thunderstorms may be provided in forecasts up to one day ahead of the event. Forecasts are provided over a broad area because the exact locations and strengths of thunderstorms are not currently predicted well.
2. Official severe thunderstorm watch alerts from National Meteorological and Hydrologic Services are issued when the conditions for the formation of severe thunderstorms become present (ECC, 2020). Environment Canada (ECC, 2018) defines a severe thunderstorm watch as an alert stating that, “weather conditions are favourable for a storm or severe weather, which could cause safety concerns.” Severe thunderstorm watches are usually issued several hours in advance of a high probability forecast of severe thunderstorms occurring.
3. A severe thunderstorm warning alert is issued when a formed thunderstorm passes a severity criteria threshold in accordance with the intensity of rain, winds, lightning, and hail delineated by ECCC as shown in Table 1. Thunderstorms not meeting the criteria for a severe thunderstorm warning remain unwarned, though can still pose a threat. Accordingly, Environment Canada defines a severe thunderstorm warning as, “severe thunderstorm is occurring or will occur in the warned area very soon due to its observed formation and direction of movement towards the warned area” (ECC, 2020). Severe thunderstorm warnings state both the expected impacts from the storm, as well as protective actions. Severe thunderstorms assessed to likely contain heightened or extremely dangerous hazards result in Wireless Emergency Alert (WEA) notifications through wireless phones and weather radios for all individuals in the respective path of

the thunderstorm. To illustrate the differences between watch and warning alerts in Canada, the threshold criteria for each of the alerts are provided in Table 1.

Table 1. Criteria for issuing watches, warnings, extreme warnings and Wireless Emergency Alert (WEA) messages for severe thunderstorms in Canada (ECC, 2020).

Alert Type	Locality	Threshold Criteria	Inclusion of WEA Message
Standard Severe Thunderstorm Watch	National, except Nunavik*	When conditions are favourable for the development of severe thunderstorms with one or more of the following conditions: • Wind gusts of 90 km/h or greater, which could cause structural wind damage; • Hail of two centimeters (cm) or larger in diameter; or • Heavy rainfall, as per rainfall criteria, excluding those for winter and during thaw”	No
Standard Severe Thunderstorm Warning	National, except Nunavik	When there is evidence based on radar, satellite pictures, or from a reliable spotter that any one or more of the following three weather conditions is imminent or occurring: • Wind gusts of 90 km/h or greater, which could cause structural wind damage; • Hail of two centimeters (cm) or larger in diameter; or • Heavy rainfall, as per rainfall criteria (25 mm or more in 24 hours)	No
Extreme Severe Thunderstorm Warning	National	When there is evidence based on radar, satellite pictures, or from a reliable spotter that any one or more of the following three weather conditions is imminent or occurring: • Wind gusts of 130 km/h or greater; • Hail of 7cm or larger in diameter	Yes

3.1.5 Outdoor Recreational Activities and Environmental Hazards in Southern Ontario

Given the high populations, unique geography, and extended warm-weather season, southern Ontario has an abundance of outdoor recreational activities: hiking, camping, boating, going to beaches, and large outdoor events. Hiking and camping, in particular, attract millions of participants, annually, due to an abundance of outdoor areas, including more than 300 outdoor conservation areas, 113 provincial parks and nature reserves, and two national parks throughout southern Ontario (Ontario Parks, 2023). Provincial parks alone, attract over 10 million visitors, annually (Ontario Parks, 2023).

Hazards associated with high-impact weather events, such as severe thunderstorms, pose a risk to outdoor recreationists in southern Ontario. This is because the overwhelming majority of thunderstorm activity occurs in the summer months, peaking in July (ECCC, 2019) (see Figure 9), which coincides with the timing of most outdoor activities in southern Ontario and specifically with the largest number of park visits in Ontario (Ontario Parks, 2023). Studies on lightning casualties indicate that the majority of lightning casualties are people who were taking part in outdoor recreational activities during this time of the year; coinciding with common temporal thunderstorm development and related lightning incidence—during the afternoon to early evening hours (Mills, 2008, 2020; Holle et al., 2021; Burrows, 2020). For example, three hikers were struck by lightning while camping on a cliff face in August of 2005 in Killarney Provincial Park, Ontario, during a thunderstorm which led to the death of one of the hikers (CBC, 2005). Injuries have also occurred from falling trees as a result of severe thunderstorm straight line-winds in southern Ontario Provincial Parks, as was seen during the derecho event in 2022 (Ontario Parks, 2022).

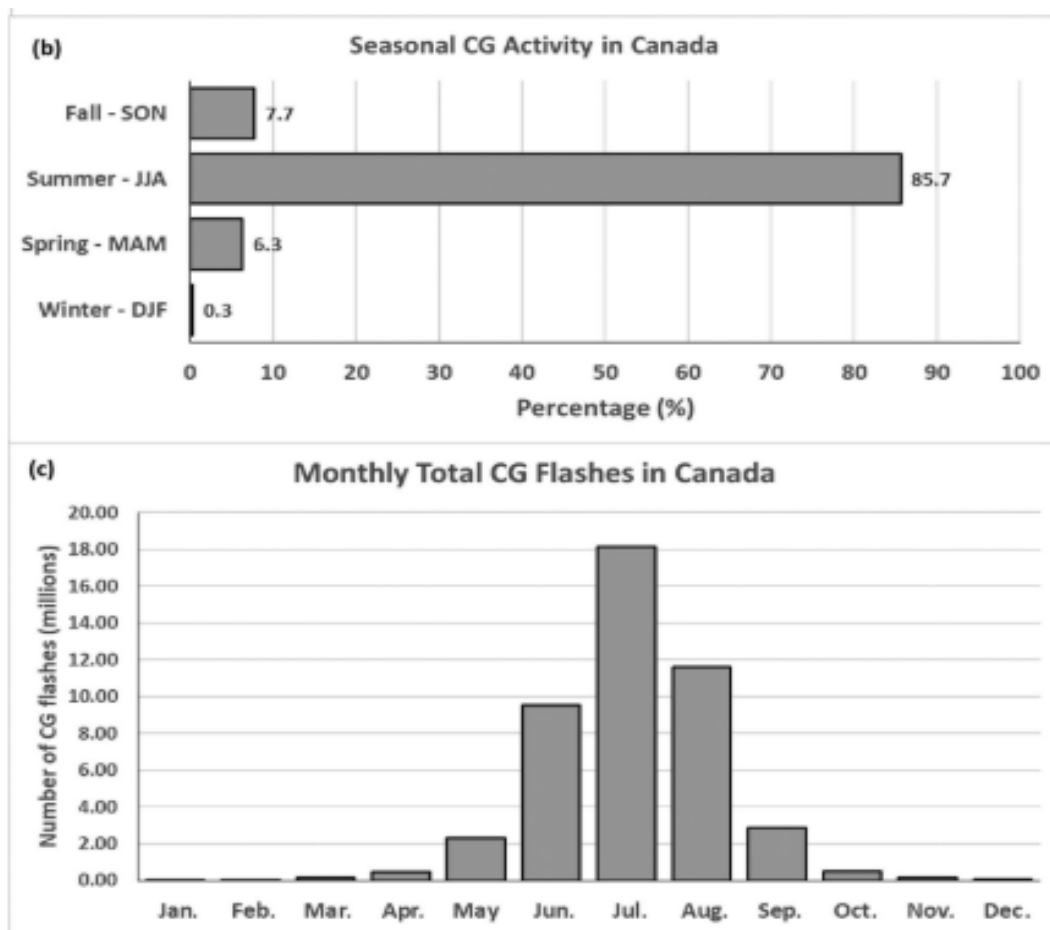


Figure 9. Cloud-to-ground (CG) lightning activity in Canada from 1999 to 2018 characterized by (b) season, and (c) month (ECCC, 2019).

The number of individuals partaking in outdoor recreational activities has increased in the past several years (Ontario Parks, 2023). According to a survey conducted for the Nature Conservancy of Canada (2021), 82% of respondents reported spending time in nature, with 37% reporting greater time in nature than before the COVID-19 pandemic. This claim has been corroborated by large increases in Provincial Park visitors; an Ontario Parks spokesperson noted in early, 2022 that camping nights grew from 4.3 million in 2014 to 6.6 million in 2021 (Ontario Parks, 2023b). In 2022, Ontario parks drew in over 12 million total visitors, a 24% increase over the previous year despite the COVID-19 pandemic and several stay-at-home orders during the same period, with the largest number of visitors in the late spring and summer months (Government of Ontario, 2023).

Given the importance of outdoor recreational activities to economic activities and human well-being, researchers have noted a need for increased understanding as to how recreationists respond to weather conditions to improve service and facility management, while reducing risk to hazards for visitors (Scott and Lemieux, 2010). While some research has been attempted to understand how people may receive, interpret and respond to weather information while outdoors (see Scott and Lemieux, 2010; Rutty and Andrey, 2014; Weyrich, 2019), no research has been done to test the influence of Emergency Alert Notifications for severe thunderstorms in Canada on outdoor activity attentiveness, risk perceptions, and decision-making. Further, the research that has taken place has not measured the effects of weather information severity across time, from a forecast all the way up to the receipt of a warning. Further, past research has failed to include attentiveness as a predictor variable, in conjunction with other variables, to assess behavioural intentions towards protective actions. This is important given that attention is a critical aspect of hazard information responses (Lindell and Perry, 2012; Silver, 2017, 2019) and some outdoor recreationists are thought to be more risk-seeking and tolerable to hazards in outdoor recreational settings (Galloway, 2002), but empirical support is scarce. To address this knowledge gap, the purpose of this study is to empirically investigate the influence of weather messaging and attentiveness on risk perceptions and behavioural responses across an evolving thunderstorm threat while outdoors doing an activity (i.e., hiking) in an Ontario Provincial park that exposes people highly to thunderstorm threats, requiring them to make decisions based off weather information that varies in severity. Overall, this research provides a closer look at lay persons behavioural responses to thunderstorm hazards.

3.2 Research Approach

3.2.1 Empirical Research Design

This study is empirical in nature, and is guided by several theoretical constructs. Within the field of environmental geography, empirical research designs are a common approach because of their investigative nature – providing an opportunity to produce primary data on human-environment interactions (Castree et al., 2009) and provide evidence to draw conclusions about human perceptions and behaviours (Ruane, 2016). Early developments in environmental

hazards research used empirical methods in the form of questionnaires to define and test parameters of risk perceptions, risk communication interventions, and their effects on changing behaviours (e.g., Saaranin, 1966; White, 1974). These studies emphasize the role of the scientific method in investigating and advancing the role of risk communication and behavioural change in hazard management (Wescoat, 1992).

Given the empirical nature of this study, a positivist research paradigm was adopted as the epistemological basis underlying this study. Positivist-centred research designs are well suited for investigating interactions between individual attributes and behavioural outcomes because they allow the researcher to observe phenomena (mostly) objectively (Creswell and Creswell, 2018). Positivist research designs primarily produce data that is used to quantitatively test relationships between variables, in a way synonymous with the scientific method (Creswell and Creswell, 2018). McGuirk and O'Neill (2016) highlight that such investigations have been used to understand the interactions between attributes and behaviours in social science studies. Given that this study seeks to understand the interactions between variables using an underlying conceptual model from social cognitive theory, a positivist approach allowed for a rigorous deductive approach to understand the role of attentiveness and other potentially influential factors on outcomes through statistical analyses. Further, much of the existing literature on the social dimensions of environmental hazards and risk has used research procedures that are predominantly quantitative (e.g., Stewart, 2009; Morss et al., 2008). Data collection methods for past studies in the field have frequently relied on primary data collected using closed-ended questions in surveys that have employed either probability (Ernst, 2021) or non-probability sampling strategies (e.g., Trujillo-Falcón, 2021). Quantitative analyses in these studies have included descriptive statistics, such as means, standard deviations, and percent frequencies or inferential statistical analysis of differences and relationships (e.g., Stewart et al., 2012; Silver, 2015; Riel and Miczo, 2024). Therefore, the procedure for this study follows that of a classic social science approach.

The research design contains an experimental aspect within the survey. Experimental designs using hypothetical scenarios are incorporated in a growing number of social science studies within the environmental hazards literature (e.g., Dewitt et al., 2015; Gutter et al., 2018;

Weyrich, 2019; Sutton and Fischer, 2020; Riel and Miczo, 2024). Experimental aspects of surveys are desirable for hazards research because they compensate for ethical, financial, time constraints, and observer biases commonly seen in observational studies of people's responses to hazards and risk communications (Dewitt et al., 2015; Gutter et al., 2018). Additionally, they provide an efficient way to gain initial insights into how people's responses may differ when confronted with risk communication practices that are yet to be tested and/or are in their infancy, in the real-world (e.g., Dewitt et al., 2019; Avey et al., 2023; Weyrich, 2019) or explore individual characteristics, cognitive processes and biases concerning the weather (Zhao et al., 2019; Sutton and Fischer, 2020; Weyrich, 2019, 2020; Armstrong and Usery, 2022). To test the effects of attentiveness and weather messaging on responses, experimental aspects provide a pragmatic way to gain insights.

3.2.2 Primary Data Collection – Questionnaire

This study is based on primary data assembled through an online self-administered structured questionnaire. Primary data was seen as essential since no publicly available datasets provide detailed insights into recreationists' perceptions and behaviours when faced with the threat of a thunderstorm in Canada.

The questionnaire included 52 questions (excluding informed consent and screening questions). Questions were primarily closed-ended (43) that yielded ordinal- and nominal-level data. The closed-ended structure of the questionnaire allowed for standardization of wording and response formats; minimizing bias and allowing for targeted questions that measured constructs that addressed the study's research questions (Hair et al., 2019; Kviz, 2019). The closed-ended questions were complemented with open-ended questions (9) that allowed participants to elaborate on their responses, facilitating a more complete understanding of their thinking. Additionally, 'other' open comment boxes were used for some of the multi-item, closed-ended questions to capture additional thoughts or items that may not have been otherwise possible. Some open-ended text answers were thematically coded to facilitate quantitative analysis (counts, frequencies of keywords/phrases of themes). More detail on the coding techniques is found in the analytical methods (section 4.3).

Several of the questions were adapted or drawn directly from questionnaire instruments used in previous studies that examined responses to risk messages (see Gutter et al., 2018; Weyrich, 2019), weather salience (see Silver, 2015; Stewart, 2009), past experiences with thunderstorms and tornadoes (see Sutton et al., 2021), and thunderstorm scenarios (see Gutter et al., 2018; Morss et al., 2018; Potter et al., 2018; Weyrich, 2019; Sutton et al., 2021; Armstrong and Usery, 2022) to collect measures of the target variables.

Additionally, the questionnaire gathered general demographic characteristics of participants in order to: (1) observe the effect of different sociodemographic variables on the other factors of the study; controlling for them during statistical analyses, (2) determine the similarity of the sample to the population of southern Ontario, and (3) provide inferences about the target population through the sample.

The online questionnaire went through several iterations based on feedback from ethics, supervisors, and colleagues who specialize in hazards research before being created using *Qualtrics* survey software and disseminated to potential participants. The final questions can be organized into several themes (Table 2). The complete survey instrument and questionnaire can be found in Appendix A.

Table 2. Summary of themes and corresponding sections of questions in the questionnaire instrument.

Theme	# of Questions	Question Format(s)	Questions
Informed consent	2	Yes-no; Nominal data	“I have read and understand the above information. I have printed a copy of this form if desired. Please indicate whether you would like to participate in this study.” , “Please indicate whether you consent to the use of quotations from text-entry questions....”
Section 1 – Screening to ensure respondents are part of the target population	3	Yes-no; nominal data (3 questions).	“Are you 18 years or older?” “Do you currently live in southern Ontario?” “Have you gone camping and hiking, at least once, during the spring, summer, or fall in the last two years?”
Section 2 – General weather attentiveness	7	Ordinal-level data indicating frequency (4 questions); Likert scale indicating level of agreement (3 questions)	“I take notice of changes that occur in the weather”, “I notice how the clouds look during various kinds of weather”, “I plan my day around what the weather may bring”, “I check the weather more often when planning for outdoor recreational activities away from home”, “I check the weather more often when taking part in outdoor recreational activities away from home”, “How often during the spring and summer do you actively seek each of the following forms of weather communication”, “the following conditions prompt me to pay greater attention to the weather”
Section 3 – Frequency of weather communication medium(s) usage	1	Ordinal-level data indicating frequency (1 question)	“How often during the spring and summer do you actively seek each of the following forms of weather communication”

Section 4 – Preferred intrusive weather alert communication medium	1	Nominal level data indicating preference (1 question)	“If you are outdoors and taking part in recreational activities during the spring and summer months, what would be the best way to make weather alerts available to you?” “The following conditions prompt me to pay greater attention the weather” “What changes in the weather cause you concerns for your safety?”, “Describe the clouds you associate with thunderstorms”
Section 5 – Saliency of social and environmental cues	1	Ordinal data using a Likert scale indicating level of agreement (1 question)	“I check the weather because I find it interesting” “I am familiar with weather patterns that indicate the possibility of thunderstorms” “I take notice of changes that occur in the weather”, “What changes in the weather cause you concerns for safety?”, “I notice how the clouds look during various kinds of weather”, “Describe the clouds you would associate with thunderstorms”, “I plan my day around what the weather may bring”
Section 6 – General Weather Saliency	7	Ordinal-level data indicating frequency (3 questions); Likert scale ordinal data indicating level of agreement (2 questions); open-ended response (2 questions)	“How much do you know about thunderstorm safety and preparedness?”, “To what extent have you searched for information about how thunderstorms form, the dangers they pose to safety, and/or precautions people should take for them?”, “Briefly explain your understanding of the difference between a thunderstorm watch and a warning”, “Briefly explain how your prepare for severe weather when planning for outdoor recreational activities away from home in the spring and summer months”
Section 7 – Thunderstorm knowledge	4	Ordinal-level data indicating level of knowledge (1 questions); Ordinal-level data indicating degree of knowledge searching (1 questions); Open ended response (2 questions)	

Section 8 – Thunderstorm hazard perceptions	1	Ordinal level data indicating level of perceived danger (1 question)	“Rate the danger level to you that is associated with each of the thunderstorm hazards below”
Section 9 – Past experience with thunderstorms	1	Ordinal level data using Likert scale level of agreement (1 question)	“People experience thunderstorms throughout their life. Please think about your experiences with thunderstorms and indicate your level of agreement with the statements listed below”
Section 10 – Suggestions for improved weather safety in outdoor recreational areas	1	Open-ended response (1 question)	“Briefly explain what kind of messaging (both content of the message and how it is provided/delivered) you think would provide excellent weather safety at outdoor public spaces, such as campgrounds and beaches.
Section 11 – Situational Weather attentiveness, risk perceptions, and associated behavioural intentions under an evolving thunderstorm threat across three scenarios	For each scenario, there are 10 questions.	Semantic differentials (0 to 10 scale) (6 questions); nominal-level data on information sources (2 questions), open ended response (2 questions)	Details provided in section 3.3

Section 12 – Socio-demographics	4	Open-ended numerical response for age (i.e., year of birth); nominal level data on gender identity (1 question) and education (1 question); ordinal-level data on residency (1 question).	“What year were you born? (e.g., 1967)” “What gender do you most identify with?” “I’m interested in your education and training experience. Please indicate your highest level of education” “How long have you lived in southern Ontario?”
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3.3 Organization of Data for Analysis

The primary data obtained from the questionnaire was designed to investigate the influence of weather attentiveness and thunderstorm risk messaging on individuals' recreational activity responses (i.e., situation-specific risk perceptions and behavioural intentions) across an evolving thunderstorm event. Research data used for the analysis was based on the integration of two different sets of data: cross-sectional data on individuals' general receiver characteristics in relation to the weather, and data from an experiment that assessed situation-specific attentiveness, risk perceptions, and behavioural responses across an evolving thunderstorm threat.

3.3.1 Cross-sectional Data

The questionnaire included 23 questions from sections 2-10 and 12 (refer to Table 2) that were designed to obtain cross-sectional information on respondents' general receiver characteristics pertaining to interactions with the weather and thunderstorms during the warmer months (i.e., spring and summer) in southern Ontario and sociodemographic information. The primary themes to be investigated here include one high-level human-weather interaction characteristic, general weather attentiveness, as well as how other individual receiver characteristics may influence weather attentiveness (Stewart, 2009; Lindell and Perry, 2012; Silver and Andrey, 2014; Fiske and Taylor, 2017; Silver, 2017,2019). Secondary characteristics included: weather salience, frequency and preference of weather communication medium usage, thunderstorm knowledge, perceptions of thunderstorm hazards, adverse past experiences with thunderstorms, and sociodemographic characteristics. These questions obtained measurements for the general weather characteristics to (1) determine how the sample of respondents is representative of a unique subpopulation of the general public in southern Ontario, (2) enable comparisons to previous studies, and (3) determine their influence on general weather attentiveness, and the pathways of influence to decision-making during context-specific weather events as outlined in the conceptual model (refer to Figure 2).

3.3.2 Experimental Data

The questionnaire also contains 29 questions from section 11 (refer to Table 2) that were designed to form the basis of a 2 x 3 mixed-design experimental analysis of the ways in which changing situations (referred to as scenarios) affect respondents' risk perceptions, thunderstorm attentiveness, and associated behavioural intentions between two different message conditions (common or higher severity) across a thunderstorm event. The variables that were measured in this section are based, largely on relationships that have been found to be important in previous studies (for *risk perceptions* see Weyrich, 2019; Sutton et al., 2021, 2022; Lindell and Perry 2012; Gutter et al., 2018, for *attentiveness* see Coker, 1983; Reynolds, 2008; Pakan, 2022; Alarcon and Marty, 2023, for *behavioural intentions* see Silver, 2015; Gutter et al., 2018; Zhao et al., 2019; Weyrich, et al., 2019). More specifically, respondents' attentiveness, risk perceptions, and behavioural intentions were tested over time by using three different types of alert messages: thunderstorm forecast (scenario 1), watch (scenario 2), and warning (scenario 3). Each of the scenarios placed the hiker at a different place in their hike with evolving temporal dimensions (i.e., at the campground just before they start the hike; approximately one hour away from the campground as they are part-way into the hike; and approximately two hours away from the campground, well into the hike). The different weather information presented at the three sequential and critical points in time represented a three-level within-subjects variable (i.e., weather information: forecast, watch, and warning) that indicated increasingly imminent, probable, and intensifying thunderstorm conditions during an event. The intention was to collect data in a similar way to the natural environment as used in Experience Sampling Methods (Hektener et al., 2007), accounting for within-participant variation in responses across time and in response to differing availabilities of weather-related information. The researcher noted this as an important consideration given that most cross-sectional studies only assess responses at one point in time and assume within-participant stability (e.g., Schultz et al., 2010; Gutter et al., 2018); a premature assumption as noted by recent works (see Zhao et al., 2019; Mills, 2021; Sutton et al., 2021, 2022). These questions obtained measurements for the situation-specific weather constructs in the conceptual model (see Figure 2) to address objectives 2 and 3 outlined in Chapter 1.

3.3.2.1 Experimental Procedure

In this section of the questionnaire, participants were first given a broad overview that told them that (1) they would be presented with information on a hypothetical outdoor activity away from home, (2) this information would be followed by three scenarios as part of an evolving thunderstorm threat over a day during their participation in a planned hike, and (3) they would be asked several questions about their thoughts and actions that they would take given the information provided for each scenario.

Following this, respondents were oriented to the setting, being told to imagine that they were camping at a provincial park several hours away from home their home and were planning on spending the afternoon doing a 4-to-5 hour hike in the park. Respondents were also told that the park had cellular data with no connectivity issues, that a permanent park building containing a visitor centre and washrooms were within walking distance of their campsite, and that no buildings existed on the hiking trail. Other hypothetical situations were considered, including respondents being indoors at home and at a beach near their home, but the specific “hiking” situation was chosen because it (1) portrayed a realistic situation that many campers face in southern Ontario, (2) forced people to make individual decisions, and (3) required them to consider an increasingly probable and imminent thunderstorm threat across time and place. Additionally, this situation was favoured due to the prevalence of this outdoor recreational activity in southern Ontario and the elevated safety risk it poses to individuals for lightning and other thunderstorm hazards (Mills, 2008, 2020; Holle et al., 2021).

Following the introduction, participants were randomly assigned to one of two groups (group A or Group B). Accordingly, half of the participants were included in a common-severity thunderstorm condition (Group A) and half were included in a higher-severity thunderstorm condition (Group B), where the official alerts, i.e., watches and warnings, contained information expressing heightened severity of impacts from expected hazards. More specifically, the common severity thunderstorm watch stated the development of severe thunderstorms with isolated nickel-sized hail and 90 km/h wind gusts and the higher-severity watch included 120 km/h wind gusts and the possibility of nickel to toonie-sized hail, as well as the possibility of a tornado. Additionally, the higher-severity watch stated the impacts of wind and hail on people

and property and the common severity information did not. For the warnings, both groups received identical warning messages stating an imminent impact from a severe thunderstorm containing wind gusts up to 90 km/h and quarter-sized hail for the area, as well as information on the expected impacts to people and property from the hazards and a call to take cover immediately if threatening weather approaches. The higher-severity group received a WEA stating the issuance of a severe thunderstorm warning for the area and a call to take cover immediately if threatening weather approaches in tandem with the warning message; the common-severity group did not receive a WEA. Specific differences in wording and display for the watches and warnings between groups A and B are found in the full questionnaire (Appendix A).

This experimental between-subjects design element, with message type as a two-level between-subjects variable (message type: common or higher severity), allowed the researcher to test the effect of higher-severity thunderstorm information on attentiveness, risk perceptions, and behavioural responses across three different points in time and space. Similarities and differences between the two conditions for each scenario are described below (Table 3). An experimental design was favoured for two reasons: (1) they reduce potential biases in samples because of their requirement of random assignment to different conditions—so that each participant has an equal chance of being assigned to one of the two conditions (Lachin, 1988; Creswell and Creswell, 2018) and (2) random assignment of large samples also increases the likelihood that the sociodemographic characteristics of the samples are proportional, and that any differences in variable measurements between groups are due to random factors (Creswell and Creswell, 2018). Ultimately, experimental designs minimize variability, by ensuring that differences based on intervening conditions are as least biased as possible, allowing for less biased explorations of causality between different conditions and outcomes (Kang et al., 2008).

Table 3. Similarities and differences between common and higher-severity message conditions for each scenario.

Scenario 1	Scenario 2	Scenario 3
Common severe thunderstorm forecast (Group A) • Receival time: 2 hours before hike. • Situational context: At campground • Weather information: Daily forecast with risk of severe thunderstorms in afternoon. • Emergency Alert: No Higher severe thunderstorm forecast (Group B) • Receival time: 2 hours before hike. • Situational context: At campground • Weather information: Daily forecast with risk of severe thunderstorms in afternoon. • Emergency Alert: No	Common severe thunderstorm watch (Group A) • Receival time: 1 hour into hike • Situational context: Close to campground. • Weather information: Common severity watch of favourable conditions for severe thunderstorm development. • Emergency Alert: No Higher severe thunderstorm watch (Group B) • Receival time: 1 hour into hike • Situational context: Close to campground. • Weather information: Higher severity watch of favourable conditions for dangerous severe thunderstorm development. Emergency Alert: No	Common severe thunderstorm warning (Group A) • Receival time: 2 hours into hike • Situational context: Far from campground. • Weather information: Common severity warning of imminent or occurring severe thunderstorm. • Emergency Alert: No Higher severe thunderstorm warning (Group B) • Receival time: 2 hours into hike • Situational context: Far from campground. • Weather information: Common severity warning of imminent or occurring severe thunderstorm. Emergency Alert: Yes

To gauge respondents' initial levels of attentiveness before being exposed to the scenarios, one question asked participants how likely they would be to check the weather forecast in the morning, before starting the hike. The thinking regarding the inclusion of this question is that previous studies have found that increased frequency of weather forecast access increases the likelihood of behavioural adjustments; further, outdoor recreationists use weather forecasts often when planning outdoor activities (Rutty and Andrey, 2014). After this, each participant was presented with three scenarios in the form of a graphic as would be displayed on a cellular device, as well as contextual text information for each scenario (i.e., the time of day, how long they have been on their hike and that they obtained or received a thunderstorm message on their phone). The weather information provided on the cellular devices was formatted to be consistent with actual weather forecasts, thunderstorm watches, and thunderstorm warnings disseminated by Environment and Climate Change Canada (ECCC), the government agency responsible for official government weather prediction and alerting services. The visual representation of the weather forecasts, watches, and warnings followed the layout the ECCC mobile weather application, WeatherCAN, and the actual wireless emergency alert used during a particularly strong and rare severe thunderstorm event on May 21st, 2022 in southern Ontario. The decision to include weather information on a cellular device was made based on the fact that most outdoor recreationists do not have access to traditional media (i.e., television, radio, computers) while outdoors and most people access weather information today through mobile weather applications on cellular devices. The contextual information used was based on the researcher's lived experience of outdoor camping and hiking activities in Ontario. An example of how the scenario-specific information and graphics were displayed to participants is shown in figure 10.

Scenario 3: In this scenario it has been approximately 1 hour after you received the previous message on your phone and you receive the following alert and following message on your phone. You are two hours from the campground.

Please review this information closely. You may refer back to this as needed for the next several questions.

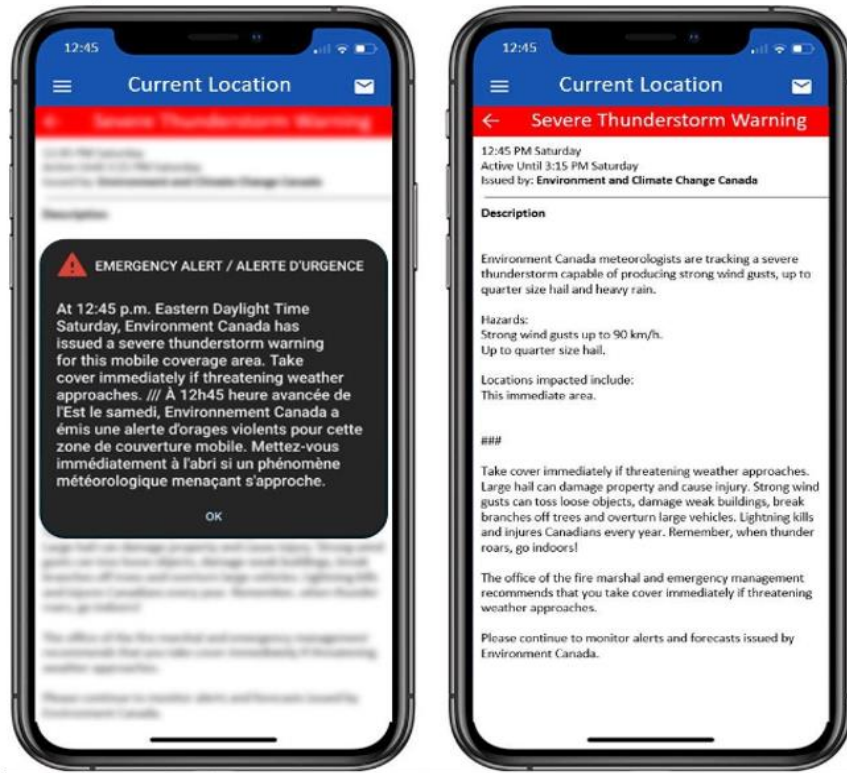


Figure 10. Mock cell-phone display of the pop-up higher-severity severe thunderstorm warning wireless emergency alert (left) and related severe thunderstorm warning information (right).

3.4 Sampling Strategy

This study used a purposive sampling strategy, which allows researchers to select a sample of individuals that best inform the investigation of a research problem and central phenomena in a study (Creswell and Poth, 2018). The sampling strategy aimed at recruiting a volunteer sample of people who are likely to participate in camping and hiking activities during the spring and summer. Given that similar studies used sample sizes between 200 and 700 participants (Zhang et al., 2007; Silver and Andrey 2015; Gutter et al., 2018), the collection of data from 300 to 600 respondents was sought. This sample size determination also met the ‘rule of thumb’ for structural equation modelling, which generally aims for 20 participants per

variable for high accuracy in the model (Kyriazos, 2018). As will be explained later, 19 variables were used, requiring a minimum sample of 380 participants (Kyriazos, 2018). Though this non-probability sampling strategy led to a non-randomized sample, other studies in the environmental hazards literature have adopted similar techniques to recruit respondents who fit a pre-defined population (e.g., Ruddy and Andrey, 2014; Silver and Andrey, 2014, 2015; Weyrich, 2019).

Given financial, practical, ethical, and time-constraints of this research, online recruitment was favoured over in-person data collection. Social media platforms (i.e., Twitter (now X), Facebook, and Reddit) were used to advertise and recruit study participants. The platforms are broadly and easily accessible and permit targeted recruitment of participants that likely fit the desired population (Kühne and Zindel, 2020). More specifically, the online survey was advertised on relevant thematic Facebook groups (e.g., Ontario Hiking, Ontario Provincial Park Camping, among others), Reddit groups (e.g., r/CampingOntario, r/OntarioHiking, r/ONProvincialPark, among others), and Twitter (now X) hashtags (i.e., #ExploreOntario, #OntarioParks, #OntarioCamping, #DiscoverOntario, #Ontario). The complete list of the groups where the survey was advertised is in Appendix B.

The survey completed ethical clearance, in compliance with the University of Waterloo's Research Ethics Board on human participant ethical observations and informed consent guidelines (REB #44484) before being disseminated to potential participants (see Appendix B). Once ethical clearance was obtained, permissions to post the survey were sought for the chosen groups: this was not a requirement for Twitter. Upon receiving permission from group administrators/moderators, a social media recruitment statement and poster that contained links as well as QR codes to access the survey were posted online. The recruitment statement and poster briefly indicated the topic of the research, "Research survey on thunderstorms & outdoor recreational activities", followed by questions related to the survey criteria for participation, a statement on the amount of time it would take to complete the survey (i.e., 15-20 minutes), the email of the researcher for questions, the statement of approval from ethics, and the survey QR code and links for access. Since social media platforms allow members of the public to share content outside of the targeted groups and populations, some snowball sampling may have occurred.

Upon accessing the survey, participants completed an informed consent letter. The letter informed participants of the voluntariness of the survey and anonymity of their collected data (i.e., no emails, names, or specific birthdates were collected). Participants were asked to indicate their consent (or not) to the use of quotations from open-ended text responses for subsequent use in study publications. Following the completion of the informed consent, three screening questions were used to screen and accept participants at the beginning of the survey:

- 18 years or older;
- Currently live in southern Ontario;
- Have been camping and hiking in southern Ontario in the last two years.

Failure to answer, ‘yes’ to all three of the screening questions resulted in prospective participants being directed to a ‘thank you’ page, notifying them that they did not meet the screening criteria and that they could not participate in the study. The survey was accessible over a three-month period (it became accessible on June 6th, 2023 and was available until August 31st, 2023).⁴ The dissemination of the survey via the chosen social media groupings took place twice – the second distribution took place two weeks after the first.

3.5 Preparing the Data for Analysis

The analysis of this empirical data is meant to investigate respondents’ general receiver characteristics and situation-specific weather attentiveness, risk perceptions, and behaviours across a thunderstorm event when weather information is of a higher severity and includes a WEA relative to common weather information alerts.

At the closing of the survey on August 31st, 629 survey responses were recorded. Of these, 51 respondents did not meet eligibility criteria, and thus their data were excluded. Respondent's data was then downloaded from Qualtrics software and formatted for analysis in *Microsoft Excel* and in the *Statistical Package for the Social Sciences* (SPSS) v. 29 software programs. To prepare the data for analysis several decisions were made related to,

⁴ This survey distribution period coincides with southern Ontario’s thunderstorm season, though no major meteorological events occurred immediately before or during this period of time, which could have led to notable biases among responses.

1. How to screen respondents whose data were not sufficiently complete.
2. What to do with missing data for individual responses to individual questions.
3. Determining the questionnaire items to be used as indicators for measuring the general receiver characteristics variables and situation-specific variables used in the analysis.
4. Organizing the data to draw conclusions, validate results, and meet the research objectives.

3.5.1 Missing Data and Data Exclusion

Two screens were used for screening out respondents: (1) Any respondent who spent less than five minutes on the questionnaire, and/or (2) Any respondent who completed less than 20% of the questions excluding the experiment. Overall, 76 participants provided no answers to the survey questions aside from questions included in the screening questionnaire and an additional 26 respondents provided answers to less than 20% of the additional questions or took less than 5 minutes to complete the survey; their responses were excluded from further data analysis. As a result, responses from 476 participants were used in the data analysis. The corresponding sample size is comparable to similar studies with regards to online surveys of the public for atmospheric hazards research (e.g., Schultz, 2010; Morss et al., 2016; Gutter et al., 2018; Nunley and Sherman-Morris, 2020).

Most of the 476 participants included in the study provided complete data. The remaining missing data was as follows:

- 0.2% to 2.7% of respondents on each of the receiver characteristics, excluding socio-demographic data.
- 0.2 % to 12.7 % of respondents on each of the experimental conditions data.

Remaining missing data were then analyzed based on separate analyses for the general receiver characteristics data versus the experimental conditions data. This was done using Little's Missing at Random Test (Little, 1988). More specifically, the test confirmed that the general receiver characteristics data were missing at random ($X^2 = 1011$, $DF = 967$, $p = 0.157$). As such, missing values were imputed and replaced for the 12 general weather characteristics missing data using Hot Deck Imputation methods (see Myers, 2011). Sociodemographic characteristics were

not replaced. Using the same test, experimental conditions data were not missing at random ($X^2=227$, $DF = 156$, $p = 0.000$), and thus no data replacement was done for these variables. The resulting samples consisted of 476 responses for the general receiver characteristics, and 440 responses for the experimental analysis, of which 222 respondents were in the common severity group and 218 in the higher severity group. The non-parametric Mann-Whitney U-Test and Fisher's Exact Test of Significance (2-tailed) confirmed that groups A and B were not statistically significantly different in terms of most demographic characteristics except for age ($p= 0.013$). To control for the varying number of responses per question for the experimental conditions data, the denominator for aggregate averages and percent frequencies were determined based on the number of responses to each question (384 to 440). For sections that required within-participant comparisons, pairwise deletions excluded participants who had missing data on any of the paired variables being tested.

3.5.2 Measures

The next step in preparing the analysis was to determine the general and situation-specific measures for the variables used in this study. There is one primary measure of respondents' general receiver characteristics in this study; the construct of general weather attentiveness. Secondary measures of respondents' general receiver characteristics include: weather salience, past thunderstorm experience, hazard perceptions, socio-demographics, thunderstorm knowledge, and weather communication media usage and preference. Items were determined to be valid in measuring each of the multi-item constructs by first adapting them from related literature and inspecting their relevancy to the operationalized definitions (Hayduck & Littvay, 2012). To statistically determine the validity that these questions belong to the constructs being measured, parallel analysis was conducted using the FACTOR software program. Additionally, to ensure that the chosen scale items demonstrated acceptable reliability, *internal consistency*—the tenant that items behave similarly on an instrument (Creswell and Creswell, 2018), for each of the total score scales for the relevant unidimensional weather-related receiver characteristics were calculated using McDonald's coefficient omega (McDonald, 1999); omega values above 0.60, indicated high internal consistency and a good fit of the items used in the relevant index scale (Stewart et al., 2009). Additionally, all variables were checked for multicollinearity using Pearsons correlation

coefficients to ensure that variables were not repeated, of which all variables scored below 4, ensuring good reliability of results and as such, no variables were excluded from analysis (Allison, 1999).

There are an additional three measures for the 2 x 3 mixed-design experiment in this study: situation-specific weather attentiveness, situation-specific risk perceptions, and situation-specific behavioural response intentions. The measures were created from subsets of items in the experimental section of the questionnaire completed by the respondents, as explained below.

3.5.2.1 Weather Attentiveness

Weather attentiveness is considered in two ways. The first is general weather attentiveness, as a receiver characteristic, and the second is situation-specific.

General Weather Attentiveness: The questionnaire provided insight into general weather attentiveness through a set of seven questions. These questions were devised based on the operationalized definition (see section 2.2.6), that weather attentiveness indicates the degree to which peoples' energies and activities are focused on the weather. The logic of including several different aspects of general weather attentiveness as indicators of the latent construct was that it allowed for reduced measurement error of the measure (Hair et al., 2019) and provided measurements of the diverse facets of general weather attentiveness. Accordingly, indicators thought to indicate perceptual (i.e., automatic recognition of weather-related aspects in everyday experiences) and reflective (i.e., extent to which weather-related matters are regularly considered and pondered on) aspects of weather attentiveness were combined as indicators of the multi-dimensional construct of general weather attentiveness.

- For the first three questions, indicating reflective aspects of general weather attentiveness respondents were asked three questions about checking the weather for planning: how often they plan their day around the weather, whether they check the weather more often when planning to take part in outdoor activities, and also while taking part in outdoor activities. The use of these items is based on research by Silver and Andrey (2015).
- Additionally, reflective aspects of general weather attentiveness were assessed by measuring each respondent's frequency of weather communication media usage using a

multi-item question about how often they actively sought different forms of weather communication. This decision reflects the general understanding that attentiveness is indicated by the active seeking of information about the subject of interest (Norton and Pettegrew, 1979; Ripberger et al., 2014; Silver, 2017 and 2019). The highest score from any of the multi-item questions was used as the indicator of general weather attentiveness (e.g., a score of 5 on one question, but 1 on all other indicators resulted in a score of 5). These questions were also used separately in section 3.6.3 (Weather Communication Media Use and Preferences) as individual explanatory variables.

- Finally, a multi-item question used as the primary indicator of perceptual aspects of the general weather attentiveness measured respondents' agreement that social and environmental conditions prompt them to pay greater attention to the weather.

These data are assembled for the entire sample and combined using aggregated averages to represent the receiver characteristic of general weather attentiveness in statistical analyses.

Situation-specific Weather Attentiveness: Attentiveness may also vary and be important in the context of specific situations rather than just as a general receiver characteristic. Section/theme 11 of the questionnaire presented three situation-specific scenarios, intentionally differing from one another in both weather information and personal situation/locations to experimentally evaluate attentiveness. To investigate the differences in attentiveness across these scenarios, an experiment was designed.

For each of the message conditions, i.e., common or higher severity, attentiveness was measured at three different points following respondents' exposure to the three scenarios (i.e., after the forecast, after the severe thunderstorm watch alert, and after the severe thunderstorm warning alert) using a set of three questions. The first of these three asked about respondents' likelihood to continue paying attention to the weather given the information they received. The second asked about their likelihood to seek out more information about the thunderstorm threat given the information they received. The third asked the frequency with which they would use their preferred weather communication media source to seek out more information about the thunderstorm threat given the information they received. Given that these three questions looked at different facets of attentiveness, each of the associated variables was used separately for descriptive analyses, T-tests,

and ANOVA analyses, and combined as indicator items for the construct of situation-specific weather attentiveness in analyses that used PLS-SEM.

3.5.2.2 Weather Salience

Another important general receiver characteristic in this study is weather salience, which is interpreted as people's inherent interest in, awareness of, familiarity with, and importance they place on the weather in their lives (Stewart, 2009; Silver and Andrey 2015). Five items were measured, each on a 5-point ordinal scale. Weather awareness and sensitivity included two questions, where participants were asked (1) how often they notice changes in the weather and (2) how often they notice how the clouds look during various kinds of weather. Weather interest included a question asking participants to rate the level of agreement that they check the weather because they find it interesting. Familiarity was measured by asking participants to rate their level of agreement that they are familiar with weather patterns that indicate the possibility of thunderstorms. The importance of the weather in their lives was measured by asking how often respondents plan their day around the weather. Each question constituted an indicator item, which were combined using aggregated averages to measure the general receiver characteristic of general weather salience.

3.5.2.3 Weather Communication Media Usage and Preferences

Another important general receiver characteristic in this study is weather communication media use and source preferences, which is interpreted as people's preferred mediums that they access weather from during the warmer-months and the frequency of their active usage. Six items were measured, each on a 5-point ordinal scale, where participants were asked how frequently they actively seek out weather information through each of the mediums during the spring and summer months. Classic communication mediums included radio, television/news networks, and word-of-mouth choices; whereas online communication mediums included websites, social media, and mobile apps. Each question constituted a variable representative of each weather communication media that were used separately in statistical analyses and assembled for the entire sample.

3.5.2.4 Past Thunderstorm Experience

Another important general receiver characteristic used in this study is past thunderstorm experience, which is interpreted as the negative perceptions about a prior thunderstorm event(s) from direct and indirect impacts (Demuth, 2018). For past thunderstorm experience, participants were asked using a multiitem question of three statements about the level of fear or worry they felt as a result of past thunderstorm experiences in their life for (1) their own life, (2) their loved ones, and (3) their home and/or property. This question was adapted from Sutton et al., (2021). These data are assembled for the entire sample and each of the items (i.e., fear for self, fear for loved one, and fear for home/property as a result of experiences) were used as indicators, which were combined to measure the general receiver characteristic of past thunderstorm experience.

3.5.2.5 Thunderstorm Hazard Perceptions

Another important general receiver characteristic in this study is hazard perceptions of thunderstorm hazards, which is interpreted as one's level of perceived danger (Morrow, 2009). General hazard perceptions were determined by asking participants to rate the danger level they associate with different thunderstorm hazards (i.e., lightning that strikes the ground, straight-line winds not associated with a tornado, heavy rain/flash flooding, hail large enough to damage cars, and a tornado). The decision to include questions aimed at assessing respondents' perceptions regarding the different hazards in thunderstorms was based on literature proposing that the emotional valence (i.e., risk as feeling) people associate with these hazards may influence their saliency and therefore attention towards thunderstorms (Lindell and Perry, 2012; Stewart et al., 2012; Sutton et al., 2021; Weyrich et al., 2020). If a hazard carries greater danger perceptions to an individual, it can then be expected that they will pay more attention to it due to the domination of emotion-based, intuitive and associative thinking pathways (Weyrich, et al., 2020; McCaughey et al., in review). These data are assembled for the entire sample and the five items were used as indicators, which were combined using aggregated averages to measure the general receiver characteristic of general thunderstorm hazard perceptions.

3.5.2.6 Thunderstorm Knowledge and Preparedness

Another important general receiver characteristic in this study is thunderstorm knowledge, which refers to one's understanding of thunderstorm information, formation, and preparedness and safety activities surrounding them (Nunley and Sherman-Morris, 2020). Thunderstorm knowledge was assessed using a set of three questions assembled for the entire sample.

Thunderstorm knowledge is a multidimensional construct; two questions provided a measurement of respondents' self-perceived level of thunderstorm knowledge and one question assessed their level of thunderstorm knowledge.

- For the first two questions, indicating respondents' self-perceived thunderstorm knowledge, respondents were asked: their self-perceived knowledge levels of thunderstorm safety and preparedness and secondly, the extent to which they have searched for information about how thunderstorms form, the dangers they pose to safety, and/or precautions people should take towards them.
- For the last question, indicating respondents' assessed thunderstorm knowledge, respondents were asked to differentiate between severe thunderstorm watches and warnings and responses were coded as 1 = no differentiation, 2 = partial understanding, and 3 = full understanding. Further details and examples of the scoring for this variable is provided in Chapter 4.

It was important to include a question that actually assessed respondents' level of thunderstorm knowledge, given that self-perceived responses generally overinflate people's actual level of knowledge by the Dunning-Kreuger effect (Nunley and Sherman-Morris, 2020). While not used in statistical analyses, two open-ended response questions asked participants to describe how they prepare for severe weather when planning outdoor recreational activities and what kind of messaging they think would provide excellent weather safety at outdoor areas to discern further insight on participants' thoughts and provide further evidence for recommendations that are presented in the final chapter of this thesis. The three indicator items were used to measure weather knowledge; two items were for self-perceived knowledge dimension and one was used for the assessed knowledge dimension. These data are assembled for the entire sample and combined to represent the construct of general weather knowledge in statistical analyses. Given

that assessed knowledge used a different scale (1 to 3) than the two self-perceived knowledge responses, data were standardized to provide an unbiased thunderstorm knowledge index, whereas the range was stretched to 1 to 5. For example, a respondent with a score of 1 on assessed knowledge would score 1 (out of 5); a score of 2 would convert to 3 (out of 5); a score of 3 would convert to 4 (out of 5).

3.5.2.7 Sociodemographic Characteristics

Sociodemographic characteristics of respondents may modify the influence of other variables examined in the study, including, weather salience, weather attentiveness, knowledge, and behavioural intentions, as well as have independent effects. Four questions were used to measure: age, gender, education level, and length of residency in Ontario. These data are assembled for the entire sample and the four variables were used separately in statistical analysis as independent variables and as covariates for some inferential analyses.

3.5.2.8 Risk Perceptions

Another important concept used in this study is risk perceptions, which is interpreted as one's level of personal interpretations of risk, i.e., their judgements, thoughts, and feelings about risks they face from a hazard threat based on their exposure and vulnerability. The decision to include a question assessing respondents' risk perceptions was based off empirical findings that risk perceptions are currently considered one of the strongest predictors of protective action behaviour (Schmidlin et al., 2009; Sherman-Morris, 2013). Situation-specific risk perceptions were measured in the experimental component of the survey using one question. Respondents were asked to rate the level of risk that each of the three scenarios posed to their safety. The single item was used as an indicator for measuring the construct of situation-specific risk perceptions in each of the scenarios.

3.5.2.9 Behavioral Response Intentions

Another important concept in this study is behavioural intentions, which are interpreted as the desire to take action to reduce the risk of being negatively impacted by thunderstorm hazards. Situation-specific behavioural intentions were measured in the experimental component of the survey. Hypothetical situations are used in this study as a convenient way to provide a proxy for

actual behaviours expected during real-world situations despite being imperfect proxies (Weyrich, 2019, 2020). Behavioural intentions were assessed using two different indicators, hiking activity participation and immediate protective action likelihoods. The first item measured respondents' likelihood to begin (forecast scenario) or continue (watch and warning scenarios) to participate in their hike. The second item measuring respondents' likelihood to take immediate protective actions given the thunderstorm threat and was measured for the watch and warning scenarios. These data are assembled for section 11 of the questionnaire and variables are used separately in statistical analysis.

Table 4. Summary of general weather receiver characteristics measures.

General Weather Characteristics	Index score range	Internal Reliability (ω)
Attentiveness (7 total items) Refers to the degree to which people's energies and activities are focused on the weather; expressed through the degree to which official messages and alerts, social and environmental cues prompt one to pay greater attention to the weather.	1 = Very low weather attentiveness to 5 = Very high weather attentiveness	0.80
Weather Salience (5 total items) Refers to people's inherent interest in, awareness of, familiarity with, and the importance they place on the weather in their lives.	1 = Very low weather salience to 5 = Very high weather salience	0.67
Hazard Perceptions (5 total items) Refers to the degree of danger one associates with different thunderstorm hazards (i.e., lightning that strikes the ground, straight-line winds not associated with a tornado, heavy rain/flash flooding, hail large enough to damage cars, and a tornado).	1 = Very low hazard perceptions to 5 = Very high hazard perceptions.	0.78
Past Experience (3 total items) Refers to the negative perceptions about a prior thunderstorm event(s) from direct and indirect impacts.	1 = No past experience with thunderstorms to 5 = High past experience with thunderstorms	0.81

Thunderstorm Knowledge (3 total items) Refers to one's understanding of thunderstorm information, formation, and preparedness and safety activities surrounding them.	1 = Very low thunderstorm knowledge to 5 = Very high thunderstorm knowledge	0.72
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3.5.3 Analytical Techniques

The next step in preparing the data analysis was to organize the data and determine the analytical techniques to best meet the objectives.

The first part of the analysis, for which the results are presented in chapter 4 (section 4.2) is an investigation of the influence of the two different weather messaging conditions and the three different scenarios on situation-specific weather attentiveness across the simulated thunderstorm event to meet objective 2. These data were organized in several different ways to gain explanatory power and the analytical approach followed several steps in sequential order:

1. Estimate levels of attentiveness at the three different points in time and information levels across a thunderstorm event.
2. Investigate the effect of the escalating nature of the simulated thunderstorm event on attentiveness.
3. Estimate differences in attentiveness between common- and higher-severity message conditions.
4. Investigate the effects of higher-severity message conditions on changes in attentiveness across a thunderstorm event.

The analysis for the first step involved descriptive statistics, namely inspections of frequency graphs, percent frequencies, means, and standard deviations for each of the indicator variables of situation-specific attentiveness.

The analysis for the second step involved inferential statistics, namely repeated measures ANOVA to see the effect of the escalating nature of the scenarios on attentiveness, as a whole, followed by one-sample t-tests of changes (Δ) across scenarios to determine if changes between forecasts and

watches or watches and warnings have greater effects. Post-hoc tests using Bonferroni correction determined any statistically significant effects ($p < 0.05$).

The analysis for the third step involved descriptive statistics, namely inspections of differences in means, percent frequencies, and frequency graphs.

The analysis for the fourth step involved inferential statistics, namely a 2x3 mixed design ANOVA to see the effect of message conditions severity on attentiveness across a thunderstorm event, as a whole. This was followed by independent samples t-tests of differences between changes (Δ) across scenarios to determine whether message conditions have any significant effects on changes between forecasts and watches or watches and warnings.

The next section for this analysis, for which the results are presented in Chapter 4 (Section 4.3) is an investigation into the pathways of influence to behavioural responses during a simulated thunderstorm event to meet objective 3. These data were organized and the analytical approach for this section followed several steps in sequential order.

1. Model and investigate the pathways of influence from situation-specific attentiveness to behavioural responses across a thunderstorm event.
2. Investigate whether these pathways of influence are different between common and higher severity message conditions.
3. Investigate the influence of general receiver characteristics on the pathways of influence to behavioural responses across a thunderstorm event.
4. Model and investigate the influence of general receiver characteristics on general weather attentiveness.

The first step of the analysis assessed the influence of situation-specific attentiveness and situation-specific risk perceptions as independent variables and mediating/intervening variables on the dependent variables related to behavioural response intentions, namely participation and protective actions as the dependent variables (see Figure 11). The modeled relationships were based off of the conceptual framework (Figure 2) and theoretical frameworks, i.e., PADM and model of attention creation during extreme events, whereas, attentiveness relates to risk perceptions and behavioural responses, and risk perceptions relate to behavioural responses (Figure 11).

Relationships were first investigated sequentially to determine if situation-specific weather attentiveness, risk perceptions, and behavioural responses at previous points in time all significantly predict corresponding increases at later points in time. Next, relationships were investigated cross-sectionally to determine the pathways of influence during each scenario, i.e., at each point in time. More specifically, to determine if attentiveness significantly influences risk perceptions, and in turn, if risk perceptions significantly influence behavioural responses during forecasts, watches, and warnings. Lastly, cross-lagged relationships between the different variables were investigated across scenarios. Further details of these analyses are discussed in the following chapter (Chapter 4 – Results).

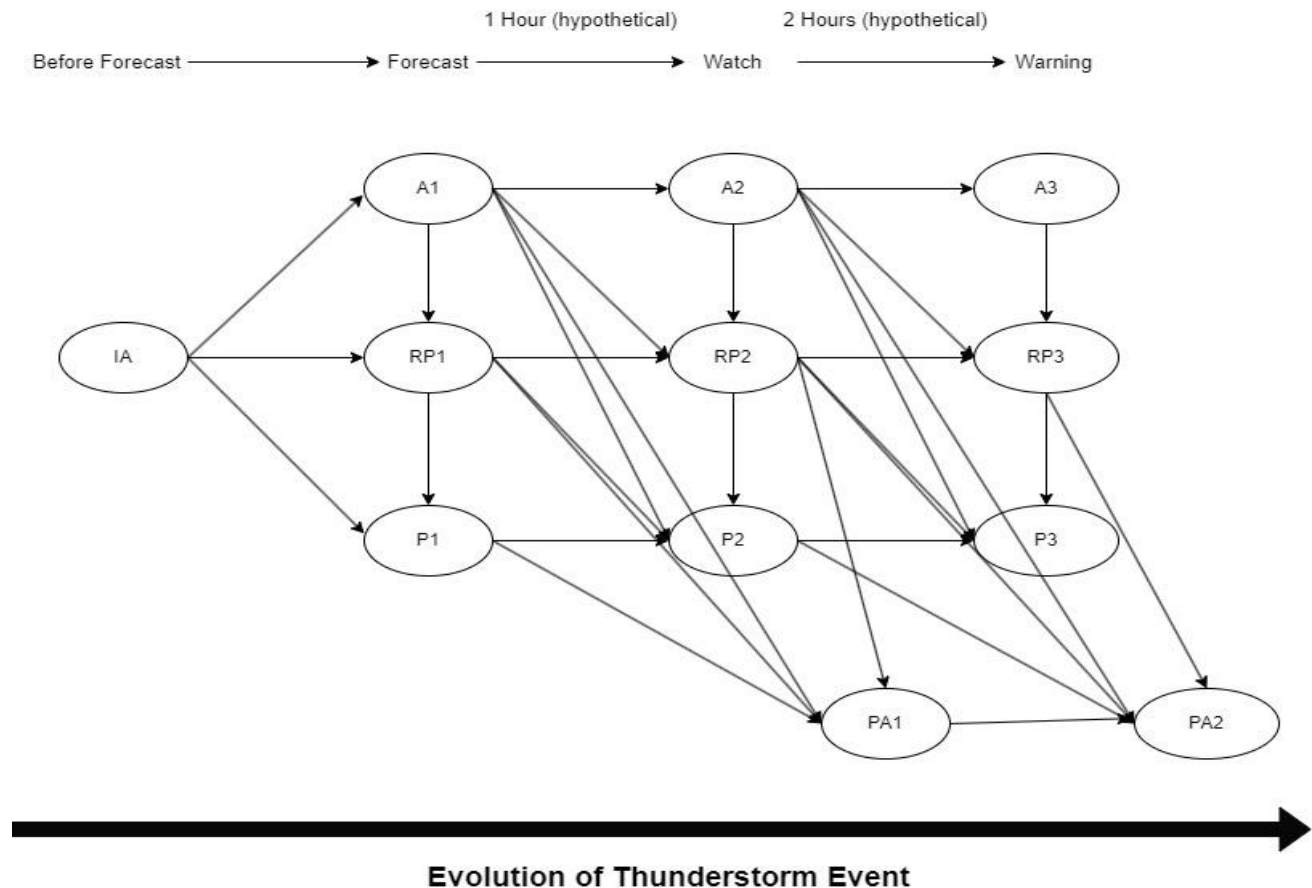


Figure 11. Model of the pathways of influence to behavioural responses across a thunderstorm event.

Note* IA = Initial Weather Attentiveness, A = Thunderstorm Attentiveness, RP = Risk Perceptions (i.e., perceived severity), P = Participation, and PA = Protective Actions.

Investigating the relationships proposed involved the use of path analysis via a partial-least squares structural equation regression model (PLS-SEM) carried out using SmartPLS-4 software. The procedure consisted of a bias-corrected and accelerated bootstrapping procedure with 5000 iterations—a sufficient amount to test the significance of coefficients in a non-parametric sample with high reliability (Hair et al., 2017). The logic for the use of PLS-SEM for the analytical approach in this section is explained further in Appendix B.

For all variables, data were standardized to give equal weight to each of the variables used in the analysis despite their differing units of measurement. Path coefficients (β values) were used to show the direction of relationships between constructs and coefficients of determination (R^2) were used to explain the percentage of variance by the model's constructs and their predictive power in the model. The model fit was assessed using standardized root means square residual (SRMR), whereas values <0.08 are considered a good fit (Henseler et al., 2014).

The second step involved the comparison of the pathways of influence between the common and higher-severity message conditions, which was completed using a multi-group analysis procedure in SmartPLS-4. The analysis is discussed in more detail in section 4.3.

The third step involved the inclusion of the potentially influential general receiver characteristics as control variables within the proposed model, for which the inspections of any significant effects on the situation-specific variables and pathways of influence are examined.

Lastly, to better understand how general weather attentiveness might be influenced by these general characteristics, a separate analysis was conducted using a PLS-SEM model. The relationships investigated are shown in Figure 12.

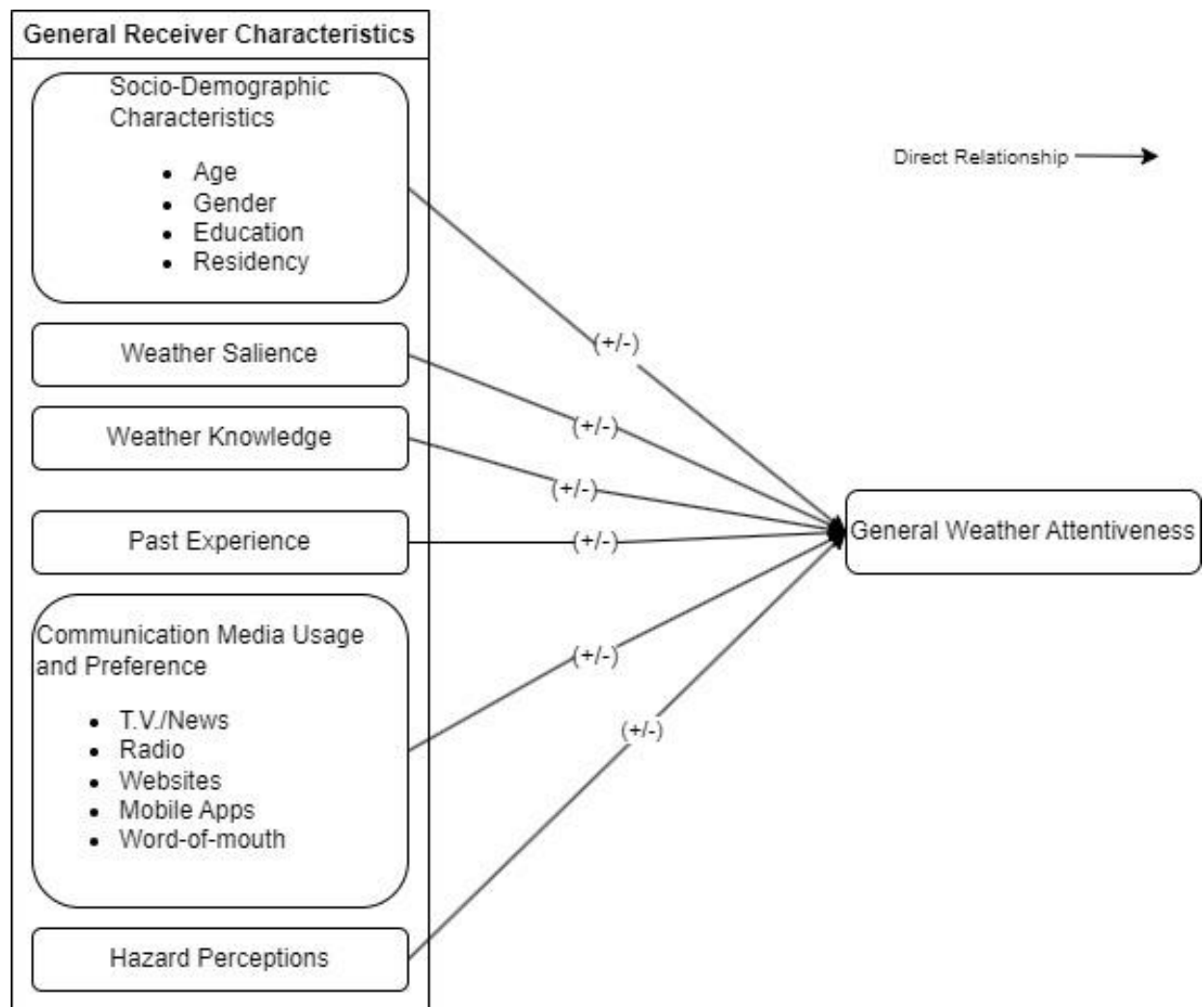


Figure 12. Proposed relationships between general receiver characteristics and general weather attentiveness.

3.6 Summary of Data

To summarize the data, individuals' general weather receiver characteristics are analyzed using descriptive statistics for each. For the second section, the situation-specific weather results are summarized by variables across the thunderstorm scenarios.

3.6.1 Summary of Individuals' General Weather Characteristics

To summarize individuals' general weather characteristics, statistical summaries were created by the use of univariate descriptive analysis of each variable: calculated aggregate means,

standard deviations, and percent frequencies. These statistical summaries for the concepts and the subsets of variables in each of them were displayed in graphical and tubular forms.

3.6.2 Summary of Differences Across Scenarios

To summarize the differences across scenarios for each of the message conditions means, standard deviations, and differences across each of the three scenarios using aggregate data were calculated. Visual illustrations of the differences were expressed through frequency distribution graphs that were compared for each of the message conditions, separately using the respective subsample.

3.7 Chapter Summary

In summary, chapter three outlines the research design and key decisions. In summary, questionnaire data used targeted online recruitment of participants. These data enabled the adoption of a quantitative approach to analysis, similar to numerous other social science studies on environmental hazards. Descriptive statistics of the data included frequencies, means, and standard deviations and graphical summaries in the form of bar graphs and box and whisker plots. Inferential statistical techniques included partial least squares structural equation modeling, where statistically significant values were reported. The following chapter applies the methodological decisions made in this chapter to analyze the data according to the research objectives set out for this study.

Chapter 4 Results

This chapter begins with an overview of the sample characteristics, including sociodemographic characteristics, and their general receiver characteristics concerning their interactions with the weather during spring and summer. The second section investigates the influence of thunderstorm messaging on attentiveness. This analysis is twofold: the first subsection presents the results of an analysis that investigates changes across time during an evolving thunderstorm event. The second subsection presents the results of an analysis that investigates the influence of thunderstorm messaging for common vs. higher severity watches and warnings. The third section presents the results of several analyses quantifying the pathways of influence affecting responses to thunderstorm messaging.

4.1 Overview of Respondent Receiver Characteristics

4.1.1 Sociodemographic Characteristics

The 476 respondents included in the data analysis are adult-aged residents of southern Ontario (79.6% women; Mean age = 41.8 years old, SD = 11.1). A summary of the sociodemographic makeup of the respondents in the sample compared to the most recent Statistics Canada population data (Statistics Canada, 2023) from southern Ontario can be found in Table 4. Inspection of the study sample's sociodemographic makeup reveals two variables are substantially overrepresented compared to the southern Ontario population: females and those with education between high school and post-secondary certificates, diplomas, or degrees. Brief explanations behind these differences in the sample compared to the general public of southern Ontario are worthy of discussion.

The overrepresentation of female respondents in the study sample is not unique to this study, as similar overrepresentations have been shown in other online surveys (Environment Canada, 2012; Nunley and Morris, 2020; Silver and Andrey, 2014). This selection bias may have multiple explanations. Firstly, women tend to participate more often than men in surveys that require voluntary participation (Smith 2008; Nunley and Sherman-Morris, 2020). This is especially relevant for surveys which require open-ended answers; women also tend to provide longer and more thought-out answers (Denscombe, 2008; Zuell et al., 2015). Other reasons for

greater response rates among women over men could be linked to their more frequent use of social media, especially Facebook (Idemudia, 2017). Also, women tend to have a higher interest in outdoor recreation than men (Rosa et al., 2020).

The overrepresentation of respondents whose highest education included post-secondary certificates, diplomas, or degrees is also not unique to this survey and may be a result of a self-selection bias phenomenon that occurs in many social science studies, in which most participants in a sample of the population are from westernized, educated, industrialized, rich, and democratic (WEIRD) participants, which make up a minority of the general population (Henrich et al., 2010). The overrepresentation may be furthered by an increasingly educated Canadian population, whereas more people are pursuing post-secondary education (Statistics Canada, 2021) and there is a high usage of social media sites, such as Facebook by individuals possessing post-secondary education (Pew Research Center, 2021). It is important to note that observed sociodemographic differences may also be partially attributed to the voluntary nature of the survey and selective online distribution via specific social media groupings consisting primarily of people who are 18 years or older, live in southern Ontario, actively hike and camp, and use social media.

Table 5. Sociodemographic makeup of the survey respondents as compared to the 2021 Statistics Canada Census profile for southern Ontario² regions.

Variable	Statistics Canada (2021)	Thesis Survey
Age (median)	45	41
Gender (% female)	51	80
Education (% with high school diploma)	30	9
Education (% with Postsecondary certificate, diploma, or degree)	53	89
Mobility Status (% resident >5 years)	65 ¹	99

¹Since this data only includes individuals who did not move from the region they resided in and does not specify whether the “movers” had moved to another region in Ontario, this may be an underrepresentation of individuals who have resided in southern Ontario >5 years.

²Southern Ontario regions include: Durham; Niagara; Peel; Waterloo; York; Halton; Prescott and Russell; Stormont, Dundas and Glengarry; Leeds and Grenville; Ottawa; Lanark; Renfrew; Frontenac; Lennox and Addington; Hastings; Peterborough; Haliburton; Kawartha; Muskoka; Northumberland; Toronto; Simcoe; Dufferin; Grey;

Wellington; Bruce; Huron; Perth; Brant; Hamilton; Haldimand-Norfolk; Oxford; Middlesex; Elgin; Lambton; Chatham-Kent; and Essex (Government of Ontario, 2022).

4.1.2 General Weather Communication Media Usage

Respondents use weather communication media to varying degrees during the spring and summer months when actively seeking out information about the weather. Most (82%) of respondents check the weather every day using at least one communication media, a similar percentage in comparison to another survey of Ontario residents consisting of the general public in two southern Ontario counties (Silver and Andrey, 2014). An investigation into the usage of each weather communication media shows that mobile apps (e.g., The Weather Network App, WeatherCAN App, Default Phone Weather Apps) were the most common source of weather information, with approximately 72% of respondents using this medium every day. Daily weather communication media usage was followed by websites (39% of respondents) and social media (27% of respondents) being used every day. Traditional weather communication media sources, namely T.V./News Networks and Radio are used least frequently. Notably, T.V./News Networks are the least used media for accessing weather information, with 49% of respondents indicating that they never use the medium for information, or that they use it less than once a month (22% of respondents). Similarly, the weather communication media, radio is used infrequently, with 41% of respondents never using the medium and 21% using it less than once a month. Interestingly, communication with other people (i.e., word-of-mouth) was used sparingly (about once a week to several times a week) by 62% of respondents (see Figure 13).

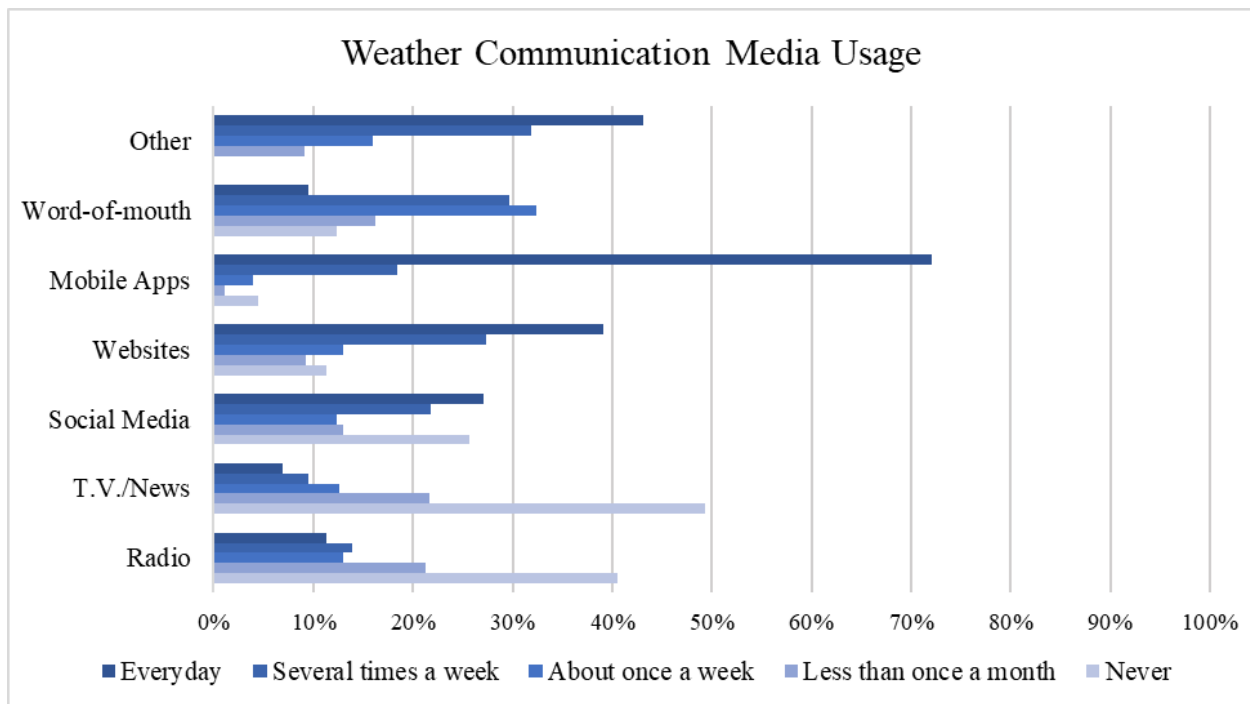


Figure 13. Frequency (%) of weather communication media usage by respondents during the spring and summer months.

When asked if there were any other sources used to access weather information, respondents included a variety of answers, with common additional sources including observing the environment (i.e., visually or audibly assessing the weather using relevant environmental cues or the behaviour of animals), subscribed weather alerts, home weather stations, weather radar and weather models, relying on historical weather patterns, home voice assistant devices (e.g., Google home and Alexa devices), online live streams, and physical weather postings in newspapers or posted at various locations pertinent to outdoor activities (i.e., visitor centres and offices for outdoor recreational areas). Interestingly, only one participant noted that they “never” or “less than once a month” checked any of the listed weather sources, though six participants used only one communication media, at least once per week; the chosen communication media being mobile apps.

Respondents were also asked generally, what would the best way to disseminate automated weather information to them while engaging in outdoor recreational activities. The overwhelming majority of respondents would prefer to be reached on their mobile device by a

visual cell phone pop-up notification with sound (63%) and/or a text message with information (31%). Other answers included weather alerts at the entrance of trails or within campgrounds, and GPS messages, since some respondents indicated they keep their phone off, do not bring one when outdoors, or stay in outdoor areas that do not have reception.

4.1.3 General Weather Attentiveness

Respondents were asked several questions that gauged their general weather attentiveness. Responses gauged both perceptual, (i.e., automatic recognition of weather-related aspects in everyday experiences) and, reflective (i.e., extent to which weather-related matters are regularly considered and pondered on) aspects of general weather attentiveness.

Responses pertaining to perceptual aspects show that the visual presence of lightning striking the ground prompts respondents' attentiveness to the weather greater than the receipt of a severe thunderstorm warning, with ~75% of respondents expressing strong agreement that the environmental cue prompts them to pay greater attention to the weather as compared to ~70% for receiving an official severe thunderstorm warning. Overall, several environmental cues (i.e., changing sky conditions, seeing lightning and hearing thunder) prompt greater weather attentiveness than less urgent official sources of information (i.e., severe thunderstorm forecasts and watches) (Table 6). Information from friends or loved ones accounted for the least influence on attentiveness, generally, followed by the visual presence of precipitation (rain or hail). Other sources indicated by respondents included sudden changes in temperature, winds, or pressure, weather alerts from apps or wireless emergency alerts, social media posts, animal behaviours, weather-related impacts on body (i.e., headaches), and presence of storms on radar.

Table 6. Agreement (% of total respondents) that environmental and social weather cues prompt attentiveness to the weather during the spring and summer months.

Weather Cue	Agree or Strongly Agree (% of total)
Changing sky conditions	97.0%
Hearing thunder	94.6%
Seeing lightning that strikes the ground	96.1%
Seeing precipitation (rain or hail)	77.8%
Mention of severe thunderstorms in forecast	86.1%
Receival of official severe thunderstorm watch	87.3%
Receival of official severe thunderstorm warning	96.7%
Thunderstorm information from a friend or loved one	57.9%
Other	29.1%

Responses pertaining to reflective aspects of general weather attentiveness found that the vast majority of respondents use communication media daily during the spring and summer months to seek out information about the weather (Mean = 4.8 out of 5) and usually plan their day around the weather (Mean = 3.9 out of 5). With respect to attentiveness pertaining to outdoor recreational activities, responses show that almost all (94%) of the respondents would check the weather before, i.e., during the planning stage, of their outdoor recreational activity. These findings of heightened weather attentiveness when planning to take part in outdoor recreational activities aligns closely with a survey of a subpopulation of Ontario residents that regularly engage in winter outdoor recreational activities (Rutty and Andrey, 2014), where ~97% of respondents in the study said they would use forecasts when planning. These results are notably higher than a study done on the general public of southern Ontario in two counties (Silver and Andrey, 2014), where 87% of respondents agreed that they would check the weather more often if it is supposed to storm. Additionally, 87% of respondents noted that they would check the weather during outdoor recreational activities. These results suggest that the sample of a subpopulation of outdoor recreationists in comparison to the more diverse general populous of southern Ontario place a greater reliance on the use of weather information when planning for and taking part in outdoor recreational activities than for other needs.

4.1.4 General Weather Salience

Respondents were asked several questions that gauged their general weather salience. More specifically, five questions investigated the different facets of respondent's weather salience: awareness, familiarity, interest in, and emotional attachment to changes in the weather from day-to-day. Overall, respondents in the study are generally highly weather salient (see Figure 14). In terms of awareness, the majority (67%) of respondents always notice changes in the weather and 48% of respondents always notice how clouds look during various kinds of weather. These results are substantially higher than a survey of the general United States population (Stewart, 2012). Most respondents (78%) also agreed that they were familiar with weather patterns indicating the possibility of thunderstorms and most (70%) agree that they plan their day around what the weather may bring. These findings are unsurprising given that the majority (85%) of respondents agreed that they checked the weather because they were inherently interested in it. This finding is substantially higher than responses from a similar study done in southern Ontario that consisted of members of the general public from two counties, where only 56% of respondents noted they check the weather because it is interesting (Silver and Andrey, 2014). Overall, these findings suggest that outdoor recreationists are substantially more weather-salient than the general population of southern Ontario.

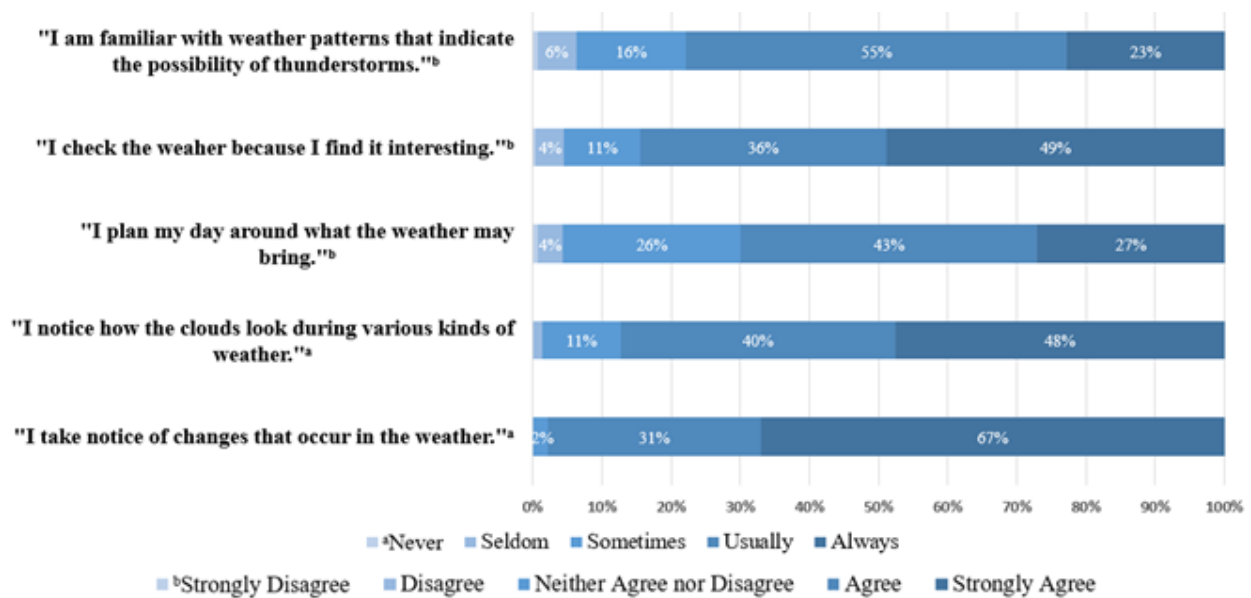


Figure 14. Responses to general weather salience questions.

4.1.5 Thunderstorm Knowledge

Respondents were asked three questions that assessed their knowledge of thunderstorms. More specifically, two questions probed respondents' self-assessed thunderstorm knowledge (i.e., their level of knowledge about thunderstorm safety and preparedness and the extent to which they have searched for information on how thunderstorms form, the danger they pose, and precautions people should take for them) and one question assessed objective thunderstorm knowledge by assessing whether respondents understand the difference between severe thunderstorm watches and warnings through an open-ended text response.

Responses pertaining to respondents' self-assessed thunderstorm knowledge show that, overall, respondents perceive that they are moderately thunderstorm-knowledgeable (Mean = 3.29 out of 5). The majority of respondents perceived that they are somewhat (51%) or very knowledgeable (41%) of thunderstorm safety and preparedness, respectively. In addition, most respondents have sought out somewhat (38%) or quite a bit (27%) of information about how thunderstorms form, their dangers, and precautions that should be taken for them. When asked about how they prepare for severe weather when planning for outdoor recreational activities away from home during the spring and summer months, some common themes were reported. The majority of respondents note that they check weather forecasts in advance of their activities

and cancel activities if adverse weather conditions are expected. In addition, many respondents note having a plan in place if severe thunderstorms are forecast while they are already camping and/or planning or already involved in outdoor recreational activities. Common themes involved marking out safe sheltering options in outdoor recreational areas, such as reinforced park buildings and continually monitoring the weather. As one respondent noted,

“If there is a possibility of severe storms I cancel my plans and stay home. If the weather changes while I am out camping and a storm is forecast I will try my best to learn the severity of the storm in terms of time, duration, possibility of a tornado, wind speeds, etc. I will then spend time either packing up my campsite or fortifying my tent with additional pegs, tarps etc. I will also make a plan to seek shelter in a campground bathroom where the structure is concrete, away from windows.”

- Female, 58 years old

When it came to differentiating a severe thunderstorm watch from a warning, the majority (71%) of respondents could differentiate between the two. This was determined by their ability to reiterate the major themes behind the different sources of severe thunderstorm information in relation to urgency, i.e., timing and likelihood of a thunderstorm event—a technique used in similar studies where respondents were asked to differentiate between the two pieces of severe weather information (see Sherman-Morris, 2010; Environment Canada, 2012; Silver and Andrey, 2014).

Responses were graded on a 3-point scale; a score of 3 was awarded when a watch and/or warning were accurately defined. Responses clearly conveyed the “less urgent” or “less severe” nature of watches, with additional wording relating to how storms were not yet occurring in the immediate or surrounding area. For severe thunderstorm warnings, a score of 3 was awarded to those respondents who conveyed the more “immediate urgency” of severe thunderstorm warnings; wording such as “imminent,” “occurring” or related wording that displayed how severe thunderstorms were happening or would be very soon in the warned area with immediate need for protective actions. As one respondent wrote, “Watch = be aware that conditions may change. Warning = take precautions as a thunderstorm is or will be occurring.”

A score of 2 was awarded if the provided answer was not detailed enough to know, without following up on their response, if the respondent understood the general theme behind one or both. These responses contained both right and wrong information or wording that was confusing, such as “possible”. In essence, an incorrect difference in the likelihood of occurrence of and the expected timing of a thunderstorm event. As one respondent explained, “A watch is issued first because there is potential for a weather event, a warning means there is a high probability of a weather event”. This response was awarded a score of 2 because it is unknown whether “high probability” is perceived as “imminent impacts” from a severe thunderstorm event that has already formed, for this respondent.

Lastly, a score of 1 was awarded if the response did not contain any correct understanding of the severe thunderstorm information or mixed up a watch and/or warning in their response. As one respondent explained, “Watch is in progress and happening and a warning is that storm is possible”.

Out of 452 respondents who provided answers, the majority (~71%) of respondents were able to accurately differentiate between both a watch and warning, scoring a three, while ~20% and ~8% of respondents provided semi- or incorrect responses, scoring a two, or one, respectively.

4.1.6 Past Experience

Several questions gauged respondents' past thunderstorm experience, a measure of the emotional impact, i.e., fear, of direct and indirect past thunderstorm experiences. Most respondents (82%) have had a direct or indirect adverse experience with thunderstorms. Respondents generally expressed greater agreement about having experienced adverse impacts to their home and property, followed by fears for others (Table 7). Direct personal experiences are more variable, with an even split of respondents agreeing and disagreeing that they have feared for themselves from thunderstorms in the past.

Table 7. Respondents' past adverse experiences with thunderstorms.

	Strongly Disagree (%)	Disagree (%)	Neither Agree nor Disagree (%)	Agree (%)	Strongly Agree (%)
I have feared for my life due to a thunderstorm	13	29	17	26	16
I have feared for my loved ones due to a thunderstorm	10	24	12	40	14
I have worried about my home and/or property due to a thunderstorm	5	13	12	48	22

4.1.7 Thunderstorm Hazard Perceptions

Respondents perceive high danger with thunderstorm hazards (Mean = 4.02 Out of 5). Tornadoes were perceived as the most dangerous hazard, with most (74%) of respondents perceiving them as a very high (Mean = 4.52 out of 5) danger to their safety (Figure 15). Large hail, damaging straight-line winds, and cloud-to-ground lightning are all similarly perceived as presenting a high danger to safety, averaging ~4 (high) out of 5 (very high) across the sample. Heavy rain/flash flooding is perceived as the least dangerous out of all the possible hazards in thunderstorms, though perceived danger levels are still elevated (Mean = 3.67 out of 5).

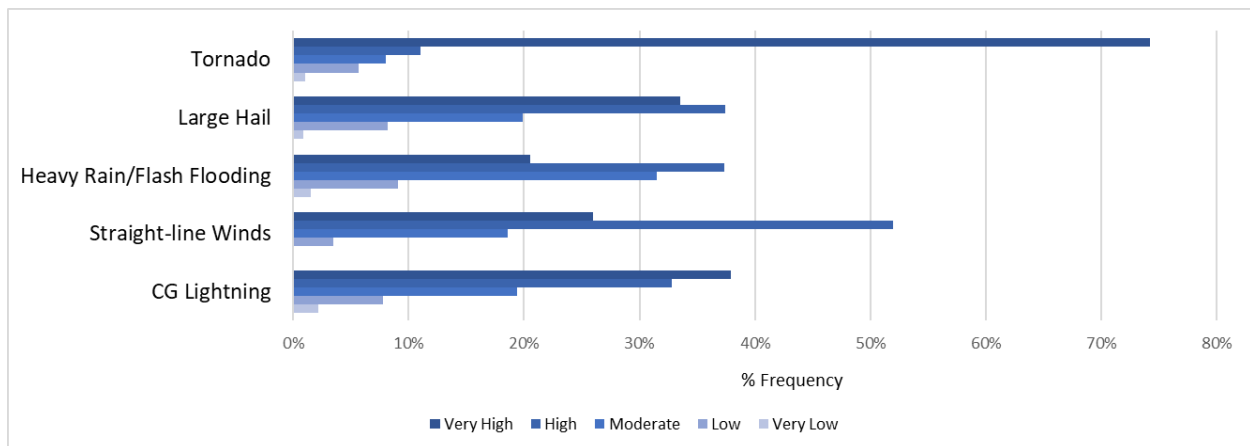


Figure 15. Hazard perceptions of thunderstorm hazards.

4.2 Influence of Thunderstorm Messaging on Situation-Specific Attentiveness

This section presents the results of several analyses concerning objective 2: investigate the influence of thunderstorm messaging on attentiveness. The first part of this analysis investigates changes across time during an evolving thunderstorm event to meet objective 2a. The second part of this analysis investigates whether attentiveness is different between common- and higher-severity message conditions to meet objective 2b. For this analysis, we will be looking at the construct of attentiveness using three indicator variables:

- Likelihood to continue paying attention to the weather.
- Likelihood to seek out additional information about the weather.
- Frequency of communication media usage to check the weather.

The situation-specific attentiveness construct is measured for two different message conditions, i.e., common and higher severity thunderstorm watches and warnings and at three different points in time. These different points in time, referred to as scenarios include a forecast, a watch, and a warning.

4.2.1 Analysis of Objective 2a: Changes Across Time During an Evolving Thunderstorm Threat

First, frequency graphs are presented to visually illustrate respondents' attentiveness across the three scenarios (Figures 16 to 18). Next, repeated measures analyses of variances (ANOVAs) are conducted to investigate the effect of the escalating nature of the scenarios from

a forecast to a watch to a warning on respondents' likelihood to be increasingly attentive to the weather in a hiking situation. This is done for each of the message condition groups separately. In a further step, one-sample t-tests are used to determine if the greatest effects are observed between scenarios 1 and 2, i.e., forecasts and watches, or scenarios 2 and 3, i.e., watches and warnings. This analysis focuses on calculated changes (Δ) across scenarios for the three indicator variables. For example, if a respondent provided a score out of 5 (out of 10) for their likelihood to continue paying attention to the weather during a forecast and a score of 9 for a watch, the change (Δ) across the scenarios would be +4.

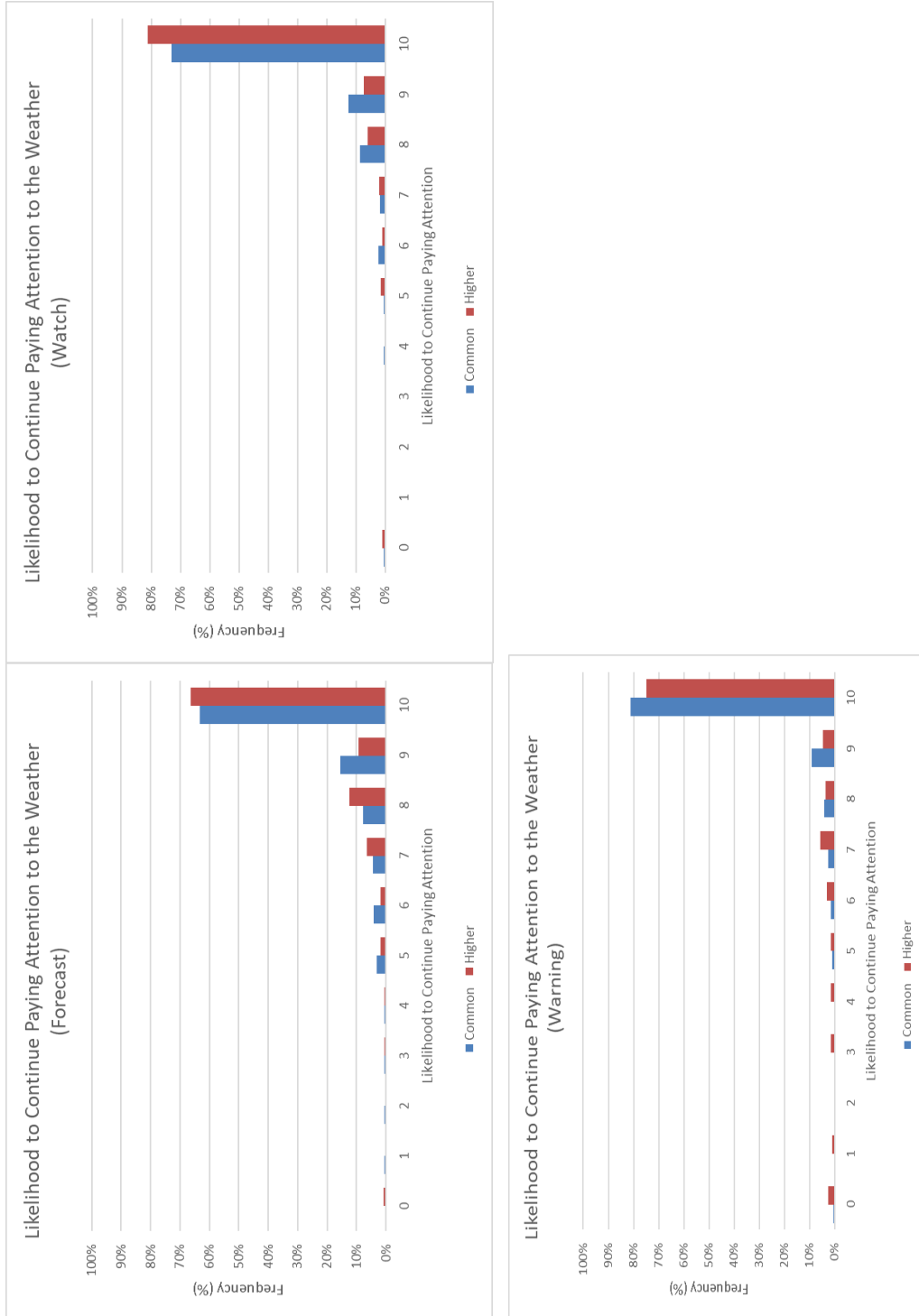


Figure 16. Likelihood of continuing to pay attention to the weather during forecasts, watches, and warnings for common and higher severity thunderstorm conditions.

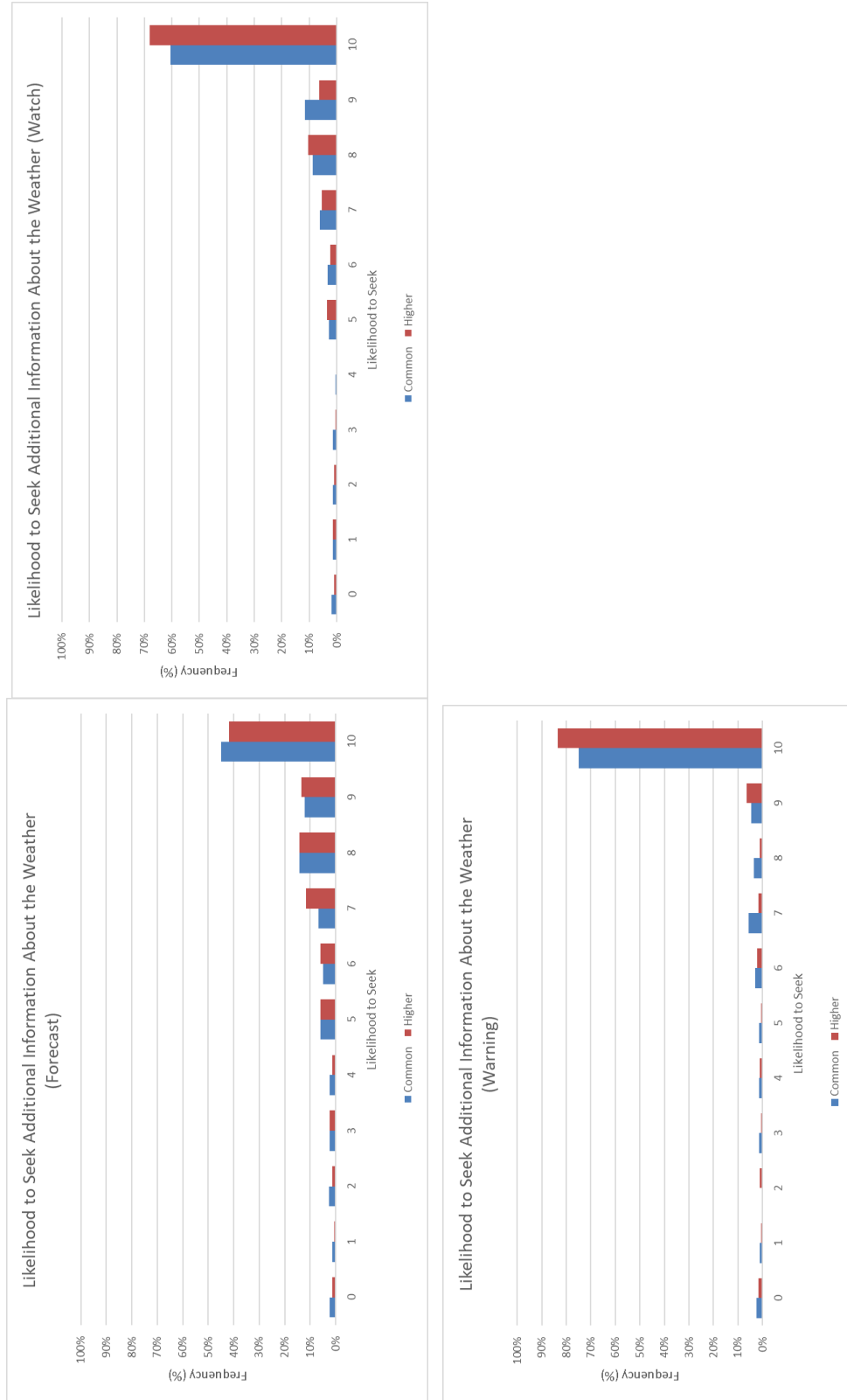


Figure 17. Likelihood to seek out additional information about the weather during forecasts, watches, and warnings for common and higher severity thunderstorm conditions.

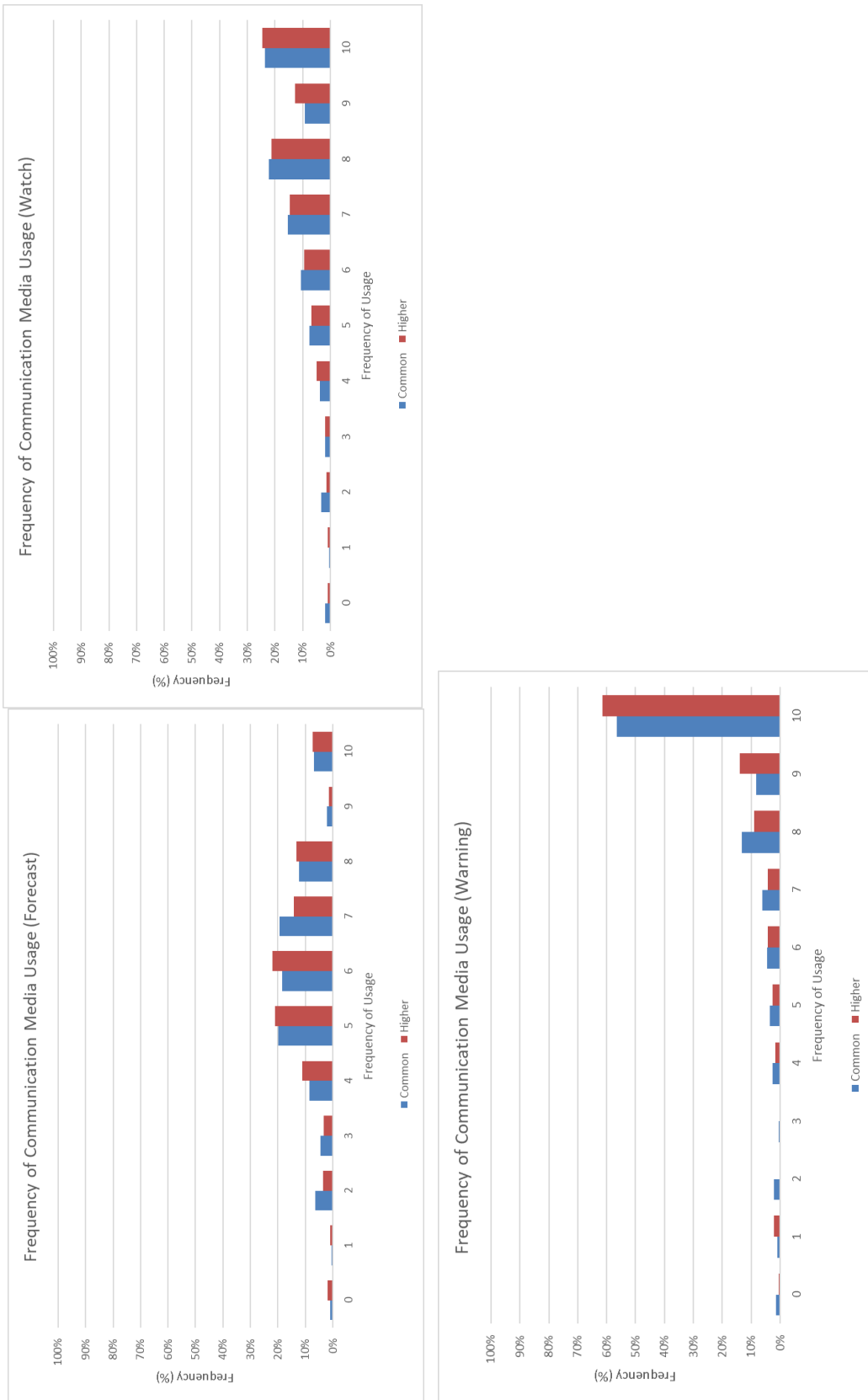


Figure 18. Frequency of Communication Media Usage during forecasts, watches, and warnings for common and higher severity thunderstorm conditions.

The information displayed in the frequency graphs (Figures 16 to 18) show that attentiveness is very high initially in response to a thunderstorm forecast for two of the three indicator variables (i.e., likelihood to continue paying attention and likelihood to seek out additional information), and this is evident for both common and higher-severity thunderstorm messaging i.e., the distributions are highly left-skewed. For the indicator variable, likelihood to continue paying attention, the percentage of participants who responded 10 (out of 10) across all three scenarios (i.e., forecast, watch and warning) was 49% for common and 52% for higher (Figure 16). Similarly, 34% of respondents for common and 33% for higher severity message conditions responded 10 (out of 10) across all three scenarios for the indicator variable, likelihood to seek out additional information (Figure 17).

The third indicator variable, frequency of communication media usage, shows a different pattern, with respondents being more variable in their responses (Figure 18). The percentage of participants who responded 10 (out of 10) under all three scenarios was only 5% for both the common and higher severity message conditions. The most common communication media used by participants across all three scenarios was mobile apps, followed by websites, and social media (~5 to 10%). As the urgency of the severe thunderstorm information increased (i.e., during watches and warnings), respondents also indicated the use of more sophisticated weather tools, such as radar and live weather coverage streams to provide them with timely and visual information that can be locally specific. Respondents also indicated a higher reliance on environmental cues (i.e., inspecting the sky visually, listening to audible sounds that indicate thunderstorm conditions, or paying greater attention to changes in air temperature and pressure) for weather information during watches and warnings.

Table 8. Results of repeated measures ANOVA analyses for situation-specific attentiveness, risk perceptions, and behavioural responses across the three scenarios for common and higher severity thunderstorm information.

Indicator Variables	F Values for Common and Higher-Severity Thunderstorm Information Conditions		Effect Size	
	Common	Higher	Common	Higher
<i>Likelihood to Continue Paying Attention to the Weather</i>	12.91** (N = 196)	8.516** (N = 188)	0.062	0.044
<i>Likelihood to Seek out Additional Information</i>	19.12** (N = 196)	33.12** (N = 188)	0.090	0.150
<i>Frequency of Communication Media Usage</i>	145.06** (N = 196)	223.87** (N=187)	0.427	0.546
<i>Risk Perceptions</i>	252.64** (N = 196)	300.38** (N=189)	0.564	0.615
<i>Participation</i>	100.62** (N= 196)	124.96** (N = 189)	0.340	0.399
<i>Immediate Protective Actions</i>	144.95** (N=196)	113.38** (N=190)	0.426	0.375

As expected, results from the repeated measures ANOVA analyses show that respondents' attentiveness increases the longer the thunderstorm event runs for both common- and higher-severity conditions (Table 8). The increases are consistently statistically significant, even though the magnitude of the average change in the score is typically less than 1 (out of 10). The effect of the escalating nature of the thunderstorm scenarios is most significant on respondents' frequency of communication usage ($F = 145.06^{**}$, $df = 2$ for common; $F = 223.87^{**}$, $df = 2$ for higher), where frequency significantly increased moderately between scenario 1 (Mean = 5.94, SD = 2.10), scenario 2 (M = 7.33, SD = 2.38), and scenario 3 (M = 8.51, SD = 2.33). Overall, communication usage went from checking every once in a while during a forecast to nearly every few minutes during a warning. Additionally, respondents' likelihood to continue paying attention to the weather ($F = 12.91^{**}$, $df = 2$ for common; $F = 8.52^{**}$, $df = 2$ for higher) and seek out additional information about the thunderstorm threat ($F = 19.12^{**}$, $df = 2$ for common; $F = 33.12^{**}$, $df = 2$ for higher) significantly increased across the thunderstorm event, though only slightly. Risk perceptions and behavioural responses also increase significantly across the thunderstorm event for both weather conditions.

Table 9. Results of one sample t-tests for situation-specific attentiveness indicators across the three scenarios.

Constructs and Indicator Variables	Change (Δ) Across Scenarios	Means (Differences in Means)		Effect Size	
		Common	Higher	Common	Higher
<i>Likelihood to Continue Paying Attention to the Weather</i>	Forecast → Watch	8.03 → 8.85 (0.85**)	8.09 → 8.95 (0.94**)	0.394	0.426
	Watch → Warning	8.81 → 9.08 (0.27*)	8.87 → 9.03 (0.16)	0.191	0.087
<i>Likelihood to Seek out Additional Information</i>	Forecast → Watch	6.81 → 7.97 (1.17**)	7.21 → 8.44 (1.26**)	0.407	0.520
	Watch → Warning	7.95 → 8.32 (0.39*)	8.43 → 8.97 (0.55*)	0.177	0.229
<i>Frequency of Communication Media Usage</i>	Forecast → Watch	5.66 → 7.18 (1.52**)	5.77 → 7.42 (1.66**)	0.741	0.835
	Watch → Warning	7.19 → 8.41 (1.24**)	7.55 → 8.84 (1.27**)	0.568	0.741

To test for variability in responses across the scenarios, an additional analysis was completed for all respondents who did not score 10 (out of 10) across all three scenarios (Table 9). Organizing the data in this way was necessary due to the absence of any variability in these responses and the focus on investigating if the escalating nature of the thunderstorm event increases attentiveness for those who were not already highly attentive to the weather. One sample T-tests of the changes (Δ) across scenarios found that attentiveness increased significantly through all scenarios for the common severity message condition group and all, but one (Watch → Warning for the variable, “likelihood to continue paying attention to the weather) for the higher severity message condition. For respondents who were not already highly attentive to the weather, the largest changes in attentiveness occurred between forecasts and watches for all three indicator variables, regardless of common or higher severity (Table 9). Changing from a

forecast to a watch and then a watch to a warning had the largest effect on the indicator variable, frequency of communication media usage.

4.2.2 Analysis for Objective 2b: Differences Between Thunderstorm Message Conditions

For the second analysis, differences between message conditions (i.e., common and higher severity) were investigated for each of the indicators using independent sample t-tests. Analyses were completed for each of the mean scores across the three different scenarios and significant differences between message conditions were determined using one-sided p-values <0.05. In the first step, differences between each of the message conditions are calculated at each point in time, i.e., each scenario (Table 10). For example, the mean scores during scenario 1 on respondents' likelihood to continue paying attention to the weather are compared between the common and higher-severity message conditions. In the second step, the changes (Δ) across scenarios are compared between the common- and higher-severity message conditions. Similar to the analyses above, to test for variability in responses across the scenarios, additional analyses are completed for all respondents who did not score 10 (out of 10) across all three scenarios (Table 11).

Table 10. Results of independent sample t-tests for situation-specific attentiveness across the three scenarios between common and higher severity thunderstorm information excluding respondents who scored “10” across all three scenarios.

Indicator Variables	Scenario	Means for Common and Higher-Severity Thunderstorm Information		Difference in Means Between Common and Higher-Severity	Effect Size
		Common	Higher		
<i>Likelihood to Continue Paying Attention to the Weather</i>	Forecast	7.97 (N=98)	7.85 (N=86)	0.12	0.064
	Watch	8.81 (N=97)	8.84 (N=81)	0.03	0.014
	Warning	9.08 (N=196)	9.01 (N=188)	0.07	0.035
<i>Likelihood to Seek out Additional Information</i>	Forecast	6.77 (N=137)	7.04 (N=138)	0.27	0.107
	Watch	7.93 (N=133)	8.35 (N=129)	0.42	0.166
	Warning	8.33 (N=121)	8.97 (N=117)	0.64*	0.253*
<i>Frequency of Communication Media Usage</i>	Forecast	5.71 (N=209)	5.67 (N=206)	0.04	0.018
	Watch	7.12 (N=197)	7.41 (N=192)	0.23	0.100
	Warning	8.42 (N=185)	8.79 (N=178)	0.37	0.165

** Significant at <0.001, * Significant at <0.05

Table 11. Results of independent sample t-tests for situation-specific attentiveness changes (Δ) between the three scenarios between common and higher severity thunderstorm information excluding respondents who scored “10” across all three scenarios.

Indicator Variables	Scenario	Means for Common and Higher-Severity Thunderstorm Information		Difference in Means Between Common and Higher-Severity	Effect Size
		Common	Higher		
<i>Likelihood to Continue Paying Attention to the Weather</i>	Forecast→Watch	0.85 (N=97)	0.94 (N=81)	0.09	0.043
	Watch→Warning	0.27 (N=208)	0.16 (N=203)	0.11	0.067
<i>Likelihood to Seek out Additional Information</i>	Forecast→Watch	1.17 (N=133)	1.26 (N=129)	0.08	0.031
	Watch→Warning	0.39 (N=121)	0.55 (N=117)	0.16	0.069
<i>Frequency of Communication Media Usage</i>	Forecast→Watch	1.52 (N=197)	1.66 (N=192)	0.14	0.071
	Watch→Warning	1.24 (N=185)	1.27 (N=178)	0.03	0.016

** Significant at <0.001, * Significant at <0.05

Results from the T-test analyses show that respondents' attentiveness is affected similarly by both the common- and higher-severity message conditions (Tables 10 and 11) across a thunderstorm event. One exception is respondents' likelihood to seek out additional information about the weather, where the receipt of a wireless emergency alert during a warning significantly increases people's likelihood to seek out additional information (Mean Difference = 0.64, $p < 0.05$). Risk perceptions and behavioural response intentions were significantly different from a forecast to a watch between the common and higher-severity weather conditions for risk perceptions and participation. More specifically, the receipt of a higher-severity watch significantly increases people's risk perceptions and likelihood of discontinuing their activity.

4.3 Pathways of Influence

The next analyses investigate the pathways of influence as outlined in the conceptual framework (Figure 2).

4.3.1 Receiver Characteristics and General Weather Attentiveness

The first analysis investigates relationships between respondents' general receiver characteristics and general weather attentiveness. This examination illuminates the influence of general receiver characteristics on their likelihood of being attentive to the weather in their everyday lives. These general receiver characteristics are myriad: sociodemographic characteristics, general weather knowledge, weather salience, thunderstorm hazard perceptions, past adverse thunderstorm experience, and weather communication media preference.

Table 12. Influence of respondents' general receiver characteristics on general weather attentiveness.

Variable	β Values
Sociodemographic Characteristics	
Age	0.034
Gender	0.057
Education	0.044
Residency	-0.049
Weather Interaction Characteristics	
Weather Salience	0.574**
Weather Knowledge	-0.145**
Past Experience	0.167**
Hazard Perceptions	0.118*
Communication Media	
T.V./News	0.066
Radio	-0.032
Websites	0.030
Mobile Apps	0.190**
Word-of-mouth	0.045

Most notably, results show that c ($\beta=0.574$) (Table 12). Additionally, those who prefer mobile apps for seeking their weather information in the summer months and those with adverse experiences with thunderstorms and higher perceived danger of thunderstorm hazards are somewhat more likely to be weather attentive, generally. Surprisingly, people with higher weather knowledge were less likely to be weather-attentive. No sociodemographic characteristics influenced respondents' general weather attentiveness.

4.3.2 Pathways of Influence to Behavioural Responses During a Thunderstorm Event

The next analysis concerns the pathways of influence during the situation-specific thunderstorm event. The purpose of this analysis is to demonstrate the pathways of influence to protective actions while outdoors hiking during an increasingly imminent thunderstorm threat; the focus is on relationships among situation-specific attentiveness, risk perceptions, and behavioural responses across time. The analysis follows the PLS model shown in Figure and is done for both common and higher severity groups, separately. The first part of this analysis begins by testing sequential effects across time of the increasing thunderstorm threat by investigating the pathways of influence between the four situation-specific variables:

- For both situation-specific weather attentiveness and situation-specific risk perceptions there are three points in time, i.e., scenarios investigated: during the retrieval of a daily weather forecast, during the retrieval of a severe thunderstorm watch, and during the retrieval of a severe thunderstorm warning.
- For situation-specific behavioural responses, two variables are investigated: likelihood of participation and likelihood of immediate protective action. The first variable, likelihood of participation, is investigated at three points in time, consistent with the attentiveness and risk perceptions variables. The second variable, likelihood of immediate protective action, is investigated at only the last two points in time, i.e., during the retrieval of a severe thunderstorm watch, and during the retrieval of a severe thunderstorm warning.

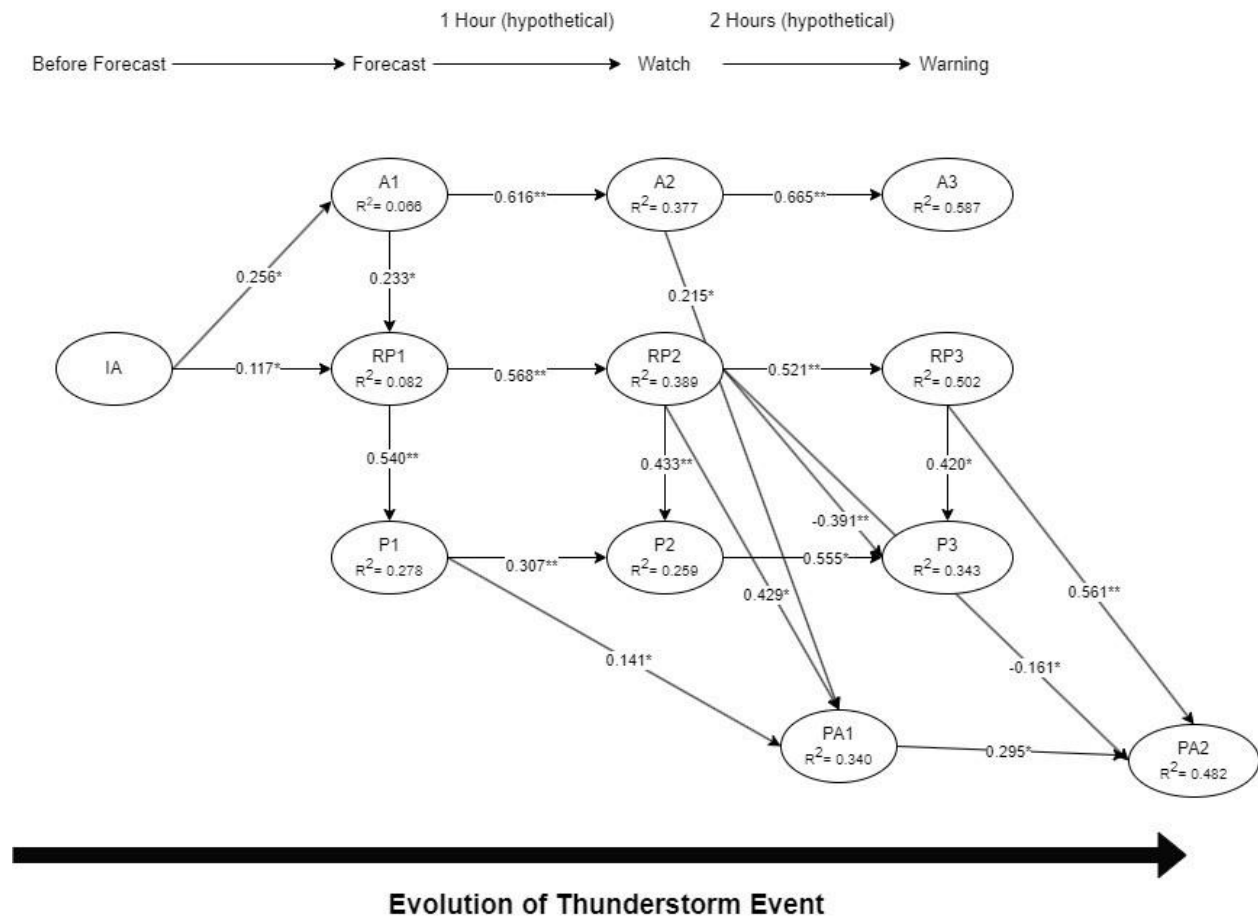


Figure 19. PLS-SEM model of the situation-specific pathways of influence for the common severity sample (n =222) across a thunderstorm event.

Notes: *significant at $p < 0.05$; **significant at $p < 0.001$. IA = Initial Attentiveness, A = Situation-specific attentiveness, RP = Situation-specific Risk Perceptions, P = Participation Likelihood, PA = Immediate Protective Action Likelihood.

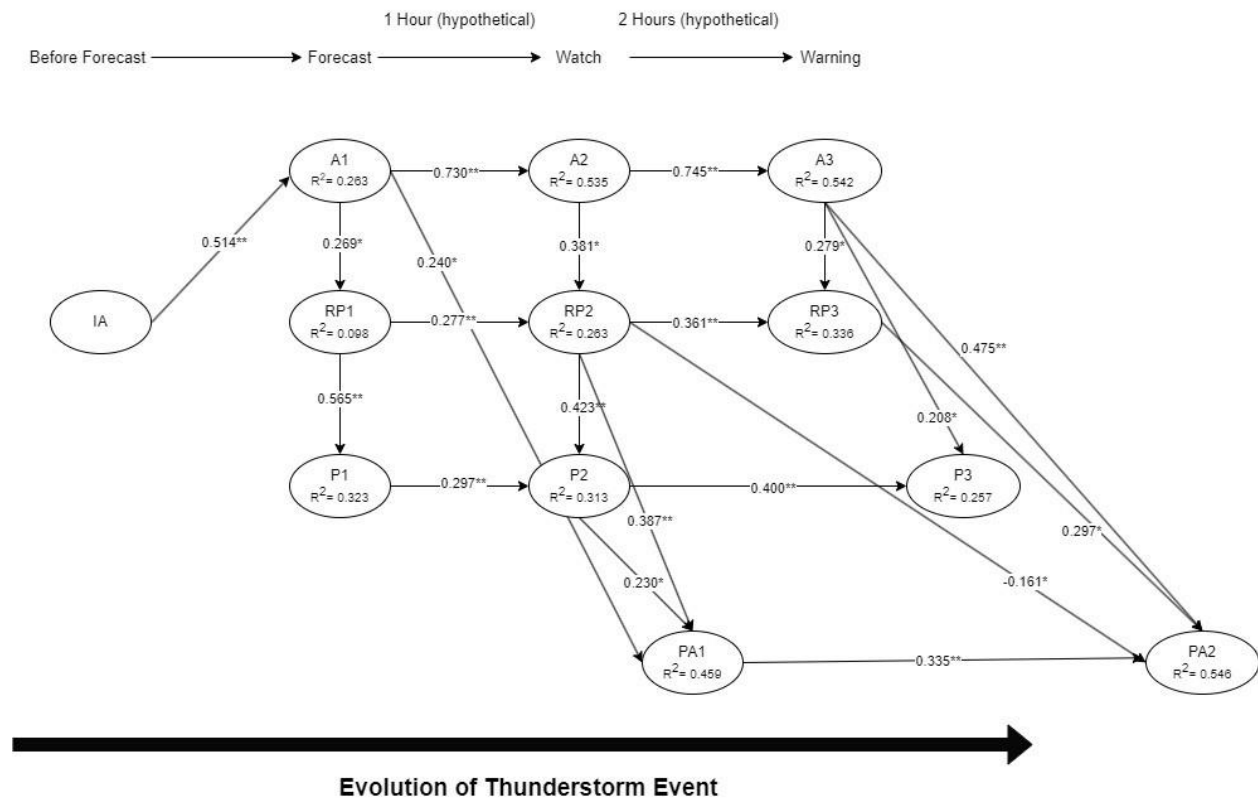


Figure 20. PLS-SEM model of the situation-specific pathways of influence for the higher severity sample ($n = 218$) across a thunderstorm event.

Notes: *significant at $p < 0.05$; **significant at $p < 0.001$. IA = Initial Attentiveness, A = Situation-specific attentiveness, RP = Situation-specific Risk Perceptions, P = Participation Likelihood, PA = Immediate Protective Action Likelihood.

Results of the sequential effects analysis for each of the situation-specific variables shows that situation-specific weather attentiveness, risk perceptions, and behavioural responses at previous points in time all significantly predict corresponding increases at later points in time (Figures 19 and 20). The strength of these relationships differs for each of the situation-specific variables, with differences between the two weather condition groups also noted for some pathways (see table 13). Situation-specific attentiveness variables show the strongest significant relationships between each of the scenarios. To begin with, initial attentiveness, as measured by respondents' likelihood to check the forecast in the morning before starting their hike, is a

significant positive predictor of respondent's attentiveness following the retrieval of a forecast containing the risk of thunderstorms, i.e., scenario 1 ($\beta = 0.254$, $p < 0.05$ for common; $\beta = 0.514$, $p < 0.001$ for higher). Following this, respondents' attentiveness at a forecast is a strong predictor of increasing attentiveness at a watch ($\beta = 0.616$, $p < 0.001$ for common; $\beta = 0.730$, $p < 0.001$ for higher) and from a watch to a warning ($\beta = 0.665$, $p < 0.001$ for common; $\beta = 0.745$, $p < 0.001$ for higher) (Figures 19 and 20). Similar findings are expressed for risk perceptions and behavioural responses for both message conditions (Figures 19 and 20).

The model also assessed pathways of influence between different variables at each point in time, i.e., within each scenario. Investigations of the pathways of influence within each scenario test whether situation-specific attentiveness predicts risk perceptions and behavioural responses and whether risk perceptions predict respondent's behavioural responses. For example, the relationship between situation-specific attentiveness and situation-specific risk perceptions during the retrieval of a watch is investigated.

- Scenario 1 (Forecast): Results of the pathways of influence within each scenario show that increased situation-specific attentiveness significantly increases respondents' likelihood to perceive a higher risk of their situation for both the common ($\beta = 0.233$, $p < 0.05$) and higher ($\beta = 0.269$, $p < 0.05$) message conditions during scenario 1. Increased risk perceptions during scenario 1 in turn amplify behavioural responses by increasing the likelihood that respondents don't go ahead with the hike.
- Scenario 2 (Watch): In the second scenario, increased attentiveness significantly amplifies risk perceptions for the higher severity message conditions, only ($\beta = 0.233$, $p < 0.05$). Increased attentiveness also increases the likelihood to take immediate protective actions for the common severity message condition, only ($\beta = 0.215$, $p < 0.05$). Amplified risk perceptions during scenario 2 amplify behavioural responses by increasing the likelihood that respondents discontinue their hike ($\beta = 0.433$, $p < 0.001$ for common; $\beta = 0.423$, $p < 0.001$ for higher) and take immediate protective actions ($\beta = 0.429$, $p < 0.05$ for common; $\beta = 0.387$, $p < 0.001$ for higher).
- Scenario 3 (Warning): In the third scenario, increased attentiveness significantly amplifies risk perceptions for the higher severity message conditions, only ($\beta = 0.279$,

$p < 0.05$). In addition, under the higher severity message conditions, increased attentiveness significantly amplifies behavioural responses by increasing the likelihood that respondents discontinue their hike ($\beta = 0.208$, $p < 0.05$) and take immediate protective actions ($\beta = 0.475$, $p < 0.001$). Amplified risk perceptions during scenario 3 amplify behavioural responses by increasing the likelihood that respondent respondents take immediate protective actions ($\beta = 0.561$, $p < 0.001$ for common; $\beta = 0.297$, $p < 0.05$ for higher).

Additionally, the model assessed pathways of influence between different variables across time. For example, the relationship between situation-specific attentiveness during a forecast and situation-specific risk perceptions during a watch. This analytical procedure was applied to both the common and higher severity weather condition groups to discern whether attentiveness at a previous scenario predicts risk perceptions and behavioural responses at a subsequent scenario, i.e., points of time during a thunderstorm event.

- Attentiveness: Results of the cross-lagged effects from scenario 1 to scenario 2 show that increased situation-specific attentiveness in scenario 1 significantly increases respondents' likelihood to take immediate protective actions in scenario 2 for the higher severity thunderstorm condition. In other words, people who are more attentive to the weather after receiving a weather forecast are more likely to immediately seek shelter after receiving a severe thunderstorm watch mentioning the possibility of thunderstorms developing that could contain heightened wind and hail threats.
- Risk Perceptions: Results of the cross-lagged effects from scenario 2 to scenario 3 shows that increased risk perceptions in scenario 2 significantly decrease respondents' likelihood to undertake behavioural responses pertaining to protective actions in scenario 3 for both message conditions. In other words, people who perceive higher risks of their situation after receiving a severe thunderstorm watch alert are less likely to seek shelter after receiving severe thunderstorm warnings mentioning the imminent impact of a thunderstorm. Additionally, increased risk perceptions in scenario 2 significantly

decrease the likelihood that respondents will stop their hike under a warning for the common message condition, only.

Analysis of the model shows that attentiveness and risk perceptions only explain a moderate amount of the variance in behavioural response variables, participation and immediate protective action likelihoods, suggesting other factors are at play in determining responses. Overall, results suggest that risk perceptions are a better predictor of behavioural responses than attentiveness during specific events, most notably during the forecast and watch stages of an event. Under a severe thunderstorm warning, these connections are more complex.

Lastly, multigroup analysis using a bootstrapping procedure of 5000 subsamples compared the pathways of influence between the common- and higher-severity message groups (Table 13). The thought behind this investigation is that if significant results are found for the same pathways of influence between the weather messaging conditions, cognitive and behavioural reactions are affected by the severity of the information and a wireless emergency alert (for a warning only). Differences were completed by subtracting β values in the higher severity group from the common severity group. For example, a β value of 0.500 in the higher severity group and a β value of 0.300 in the lower severity group results in a β difference of 0.200.

Table 13. Significantly different pathways of influence between common and higher-severity groups.

Pathway	β Differences Between Common and Higher Severity Groups
IA→A1	0.258*
A1→PA1	0.229*
A3→PA2	0.439*
RP1→RP2	-0.291*
RP2→P3	0.353*
RP3→P3	-0.348*
RP3→PA2	-0.260*

The last analysis tested whether general receiver characteristics of this sample and message conditions influenced the situation-specific variables (Table 14). For this analysis, responses from both the common and higher severity message condition groups were combined and message condition, as well as all general receiver characteristics, were used as covariates to test relationships.

Table 14. Significant pathways of influence of receiver characteristics to situation-specific attentiveness, risk perceptions, and behavioural response variables.

Control Variables	Significant Pathways of Influence (β Values)
Sociodemographic Characteristics	
Age	P2(-0.089*), RP1(0.101*), PA2(-0.122**)
Gender	
Education	P1(-0.148*)
Residency	PA2(-0.483*)
Weather Interaction Characteristics	
Weather Salience	P1(-0.226*)
Weather Knowledge	A1(0.299*)
Past Experience	A3(0.154**), RP1(0.105*), RP2(0.092*)
Hazard Perceptions	A3(-0.114*), RP1(0.183*), RP2(0.206*), PA1(0.150*)
Weather Attentiveness	A1(0.859**), P1(0.519**), P3(0.348*)
Communication Media	
T.V./News	P1(0.083*)
Radio	
Social Media	
Websites	P3(-0.063)*
Mobile Apps	A3(0.113*), PA1(-0.087*)
Word-of-mouth	
Message Condition	RP3(0.173*)

Analysis of the influence of receiver characteristics and message condition for this specific sample of outdoor recreationists in southern Ontario is as follows:

- Older respondents tend to perceive higher risk of their situation after receiving a forecast mentioning the risk of thunderstorms in the late afternoon and have lower likelihoods of taking protective actions as compared to younger respondents.
- Gender did not significantly influence any of the situation-specific variables.
- Respondents with higher education levels are more likely than those with lower education levels to continue with their hike as planned after receiving a forecast mentioning the risk of thunderstorms in the late afternoon.
- Respondents residing in Ontario over a longer period of time (defined as >5 years) are less likely than newer residents to take immediate protective actions after receiving a severe thunderstorm warning.
- Respondents with higher weather salience are more likely than those with lower weather salience to continue with their hike as planned after receiving a forecast mentioning the risk of thunderstorms in the late afternoon.
- Respondents with greater knowledge about thunderstorms are more likely than those with less knowledge about thunderstorms to be attentive to the weather after receiving a forecast mentioning the risk of thunderstorms in the late afternoon.
- Respondents with more impactful adverse past experiences with thunderstorms are more likely than those with less impactful adverse past experiences with thunderstorms to perceive a higher risk of their situation when hiking outdoors after receiving a forecast and a watch. Additionally, they are more likely to be attentive to the weather after receiving a warning.
- Respondents with heightened danger perceptions of thunderstorm hazards are more likely than those with dampened danger perceptions of thunderstorm hazards to perceive a higher risk of their situation when hiking outdoors after receiving a forecast and a watch. Increased hazard perceptions also increase the likelihood that respondents will take

immediate protective actions after receiving a watch during a hike. Surprisingly, increased hazard perceptions decrease the likelihood for respondents to be attentive to the weather after receiving a warning.

- Higher general weather attentiveness among respondents is a strong predictor of the likelihood of being attentive to the weather after receiving a forecast mentioning the risk of severe thunderstorms in the afternoon. Additionally, higher general weather attentiveness among respondents is a moderate predictor of respondents' likelihood of not going ahead with their hike as planned after receiving a forecast and discontinuing their hike after receiving a warning.
- Greater usage of communication media, T.V./News networks among respondents tends to slightly increase the perceived risk of their situation after receiving a forecast.
- Greater usage of communication media, websites among respondents tends to slightly decrease the perceived risk of their situation after receiving a severe thunderstorm warning.
- Greater usage of communication media, mobile apps, among respondents tends to increase their likelihood of being attentive to the weather after receiving a severe thunderstorm warning and slightly decrease their likelihood of deciding to cancel their planned hiking activity after viewing a weather forecast.
- For message condition, the receipt of an emergency alert in conjunction with a severe thunderstorm warning increases respondent's likelihood of perceiving a higher risk in their situation.

Chapter 5 Discussion and Conclusions

A hypothetical thunderstorm scenario involving an outdoor hiking activity allowed for the investigation into the roles that weather attentiveness and weather messaging have on responses. This study also provided investigations into the role that other receiver characteristics had on weather attentiveness, both generally, and during an escalating thunderstorm event.

5.1 Receiver Characteristics of Outdoor Recreationists

Most participants in this study were generally very attentive to the weather in their everyday lives. These findings are similar to other studies, which indicate that the usage of weather information among outdoor recreationists is elevated (e.g., Scott and Lemieux, 2010; Rutty and Andrey, 2014; Doksæter and Kolstø, 2016) and that they pick up on and interpret relevant environmental cues easily. These findings further indicate that this particular subpopulation of the broader general population of southern Ontario is generally more attentive to the weather than the general public (Environment Canada, 2012; Silver and Andrey, 2014). Investigations into the reasoning behind these findings within this study show that this may be related, in part, to other weather-relevant receiver characteristics. Most notably, weather salience, which is also notably high among this sample, indicating that outdoor recreationists are generally highly interested in the weather, familiar with changes relevant to thunderstorms, and place greater importance on changing weather in their lives. Explanations behind the elevated levels of weather saliency could be (1) that this sample of respondents increased presence outdoors allows them to also become interested and familiar with changes in the weather or (2) their increased interest in the weather may be one of the influential factors in their decision to take part in outdoor recreational activities in the first place. Additionally, factors pertaining to adverse past experiences or increased perceptions associated with thunderstorm hazards were also associated with high general weather attentiveness. These findings may be associated with increased associations of fear and dread (Slovic, 2007) that make respondents highly attentive as to avoid further adverse experiences and be exposed to dangers they perceive as high. Lastly, weather knowledge and preparedness were associated with decreased general weather attentiveness. These findings echo similar findings by Mills (2020) on lightning casualties in Canada and

suggest that increased knowledge may lead to a false sense of security, i.e., *levee effect*, and people may feel less inclined to be attentive to the weather.

5.2 Influence of Thunderstorm Messaging on Attentiveness

Investigations into how attentiveness changes across an escalating severe thunderstorm event found that most people were already highly attentive to the weather before even receiving a weather forecast as noted by their likelihood to check the weather forecast. This aligns with public survey data (Environment Canada, 2012) and studies that consisted of samples consisting of primarily outdoor recreationists (Rutty and Andrey, 2014), which found weather forecasts to be particularly useful and used frequently when planning outdoor recreational activities. Unsurprisingly, the more likely respondents were to check the forecast when planning for the outdoor hiking activity, the more likely they were to also be attentive to the weather following the actual retrieval of a weather forecast mentioning the possibility of thunderstorms later in the day.

After receiving a forecast mentioning the risk of severe thunderstorms later in the afternoon, the vast majority of respondents noted being highly attentive to the weather before taking part in a hiking activity. Respondents who were not already highly attentive to the weather became increasingly attentive across an escalating severe thunderstorm event, with changes occurring the most between the receipt of a weather forecast and a severe thunderstorm watch. When looking at the different facets of attentiveness, the frequency with which respondents use communication media to gain a better understanding of the thunderstorm threat increased most substantially across an escalating thunderstorm event. Respondents also generally maintained high likelihoods of continuing to pay attention to the weather and seek out more information about the thunderstorm threat from forecasts through the retrieval of warnings. This supports findings from previous studies that found that as hazardous thunderstorm events became increasingly imminent, people check the weather more frequently (Silver and Andrey, 2015; Potter et al., 2018; Weyrich, 2020).

Increased severity of official watch messages, followed by identical common warning messages that included (or did not include) wireless emergency alert notifications, for the most part, did not significantly affect people's attentiveness during a hiking activity that highly

exposed people to thunderstorm hazards. The only significant differences were observed for the receipt of an emergency alert for a severe thunderstorm warning, which significantly increased respondents' likelihood to seek out additional information about the thunderstorm threat. This corresponds with similar studies, which found that the receipt of higher severity alerts increases individuals' likelihood to want to confirm the threat (Weyrich, 2020c). Overall, the nominal differences in respondents' changes in attentiveness between common- and higher-severity watch and warning message conditions illustrates that respondent's attentiveness may not be affected by information of a higher severity and wireless emergency alerts when they are outdoors taking part in hiking activities. Similar findings by Weyrich (2020b), which compared responses to standard and impact-based warnings suggest that affective reactions are dominant in situations that leave people highly vulnerable and watch and warning messages are all that are needed to make people attentive to the weather. Despite these findings, it is important to note that the increased saliency of the audible sound that accompanies wireless emergency alerts was not realized in the survey and the ability to test the intrusiveness of wireless emergency alerts on enacting attention was highly constrained by the research procedure in this study. This is important given that wireless emergency alerts produce a unique sound and overriding alert image to all cellular devices, whereas common severe thunderstorm warnings produce similar cellular notifications to others such as texts, emails, etc. Research procedures better able to compare the effects of such alerts on attentional responses may therefore find contradicting results to this study. Though, the findings in this study that WEAs produce significantly higher risk perception responses may be in-part due to respondents' associations with these alerts in relation to past events (e.g., 2022 southern Ontario Derecho or recent past events that included tornado warnings). The *availability heuristic*, the tenant that people base their actions on the most recent information available on a phenomenon (Kahneman, 2011), could explain why this occurred. People who have been exposed to this emergency alert for warnings in the past (e.g., during the May 2022 Derecho), may have associated the emergency alert with this event, which was particularly devastating and was the first use of the emergency alert warnings for many people in southern Ontario (others were the result of tornado warnings). Overall, findings by Weyrich (2020c), showcase that in real crisis situations, fear and other forms of affective

decision-making dominate decision-making through automatic attentional and memory functions (Kahneman, 2011).

5.3 Pathways of Influence from Attentiveness to Behavioural Responses

To better understand what leads to behavioural responses when faced with evolving hazardous thunderstorm events, a conceptual framework based on social cognitive theory, the protective action decision model and model of attention creation during extreme events was developed. The framework was tested through an online hypothetical experiment that placed respondents in a realistic outdoor recreational hiking activity that progressed across a morning and afternoon in concert with weather information expressing incremental probability of a severe thunderstorm impact, where one group received the common watch and warning information and the other group received higher-severity watch information and a warning that included a wireless emergency alert. The pathways of influence outlined in the model and tested through this experiment provided insights into the important influence of attentiveness on the pathways of influence to behavioural responses. Most importantly, and in line with the pathways of influence towards protective actions outlined in the PADM and model of attention creation, this study found that attentiveness amplifies risk perceptions, which in turn increase the likelihood of behavioural responses when faced with a thunderstorm threat. These findings may be partially explained by the increased exposure and engagement with the weather information, which allows for respondents to better comprehend their level of risk (Silver, 2017). Similar insights are expressed in a study by Reynolds (2008), whereas increased moral attentiveness led to increased perceptions surrounding moral decisions. Given these findings, empirical studies should include attentiveness as a variable when attempting to understand the pathways of influence to protective actions and research should be done in the realm of environmental hazards that seeks to understand how to improve attentiveness.

Other potentially influential variables, referred to as receiver characteristics, relating to respondents' more general interactions with the weather and thunderstorms across the spring and summer months were also found to influence situation-specific thunderstorm responses:

- General Weather Attentiveness: Respondents with higher general weather attentiveness are highly likely to check the weather forecast in the morning before starting outdoor recreational activities. Additionally, these highly weather-attentive outdoor recreationists are likely to be attentive to the weather and decide not to go ahead with a planned outdoor recreational activity following the retrieval of a weather forecast that mentions the risk of severe thunderstorms in the afternoon. These results support the hypothesis by Silver (2019) that attention to extreme thunderstorm events influences actions and other studies on attentiveness in different contexts, which found that attentiveness predicts decision-making and related behavioural responses (e.g., Reynolds, 2008).
- Thunderstorm Knowledge: Respondents expressing increased knowledge relating to thunderstorms and how to keep safe from them are also more likely to be attentive to the weather following the retrieval of a watch. The findings that knowledge did not significantly influence risk perceptions or behavioural responses has also been noted in similar studies (Casteel, 2016; Weyrich, 2020a) and suggests that knowledge may not affect warning response during short-notice weather events to the same degree as longer-onset events, such as river flooding or heat waves (Mileti and Sorensen, 1990).
- Weather Salience: Respondents with higher levels of weather salience are more likely to go ahead with a hike following the retrieval of a forecast. These findings may relate to observed relationships between weather salience and individuals' need to experience changes in the weather (Stewart, 2012). Thus, highly weather-salient people may have different thresholds for taking protective actions to be able to observe changes in the weather up to a point where they need to respond to reduce exposure.
- Past Thunderstorm Experience: Respondents who have had increased negative past experience with thunderstorms are likely to perceive higher risk of their outdoor situations following forecasts and watches. Past experiences also amplify respondents' attentiveness following the retrieval of a warning. This aligns with previous studies that found that negative past experiences increase risk perceptions, protective action decisions, (Demuth, 2018; Weyrich, 2020b), and likelihood to continue paying attention to the weather (Silver and Andrey, 2015). Given that past experience amplifies people's likelihood to be attentive during a warning, which in turn affects peoples likelihood to

take immediate protective actions provides an explanation attempted by Silver and Andrey (2015), whereas one of the possible explanations to protective actions from past experience was that increased situational awareness, as a result of past experience led to increased likelihood of protective actions.

- Thunderstorm Hazard Perceptions: Respondents who perceive greater danger of thunderstorm hazards are more likely to perceive higher risks of their outdoor recreational situations following forecasts and watches. After receiving a warning, increased hazard perceptions dampen attentiveness. Dampened attentiveness at the time of a warning aligns with findings by Silver and Behlendorf (2023), indicating a coping and avoidance strategy to reduce the undesirability of the situation. Increased hazard perceptions also increase the likelihood of outdoor recreationists taking immediate protective actions after receiving a watch. This aligns with a similar study, which found that thunderstorm hazard perceptions increase the likelihood of protective actions while outdoors (Weyrich, 2019).
- Sociodemographic Characteristics: In terms of demographic influences, older and educated respondents and those who have resided in Ontario over a longer period are less likely to take protective actions after receiving a warning. These findings contradict another study in southern Ontario which found that increased residency, age, and education were associated with amplified protective action decisions after receiving tornado warnings (Silver and Andrey, 2015). One potential explanation is that the specific subset of the general population of southern Ontario used for this study has had increased exposure and thus, familiarity with thunderstorm events while hiking and may tend to downplay threats or be increasingly tolerant of them through an accumulation of weather-recreation experiences lacking adverse impacts (Wachinger et al., 2013; Anderson et al., 2023; Gatti and Brownlee, 2024). Given that the recognition of a weather event as an intolerable risk is required for protective action decision-making (Anderson et al., 2023) and that outdoor recreationists have been shown to be more risk tolerant, overall (Gatti and Brownlee, 2024), this serves as a plausible explanation and warrants further study.

- Communication Media Usage and Preference: Respondents who use mobile weather apps with greater frequency are more likely to be attentive to the weather after receiving a weather forecast. While beyond the confines of a deeper discussion in this thesis, one explanation for the increased attentiveness observed by these respondents may be due to the constant accessibility of weather information from these sources; a recent phenomena due to the emergence of smartphones in the last decade. This aligns with research on attention, whereas increased exposure to something leads to increased attention towards it (Fiske and Taylor, 2019). Additionally, greater usage of T.V./News Networks by respondents leads to greater perceptions of risk. These findings align with the social amplification of risk framework, where news messages and the language of meteorological presenters may heighten people's perceptions of risk (Kasperson et al., 2022). Oppositely, greater access to websites for weather information dampens risk perceptions following the receipt of warnings. One potential explanation is that the active information searching required for websites leads to a greater understanding of the thunderstorm threat relative to respondents' situations, reducing uncertainty, a factor which commonly increases risk perceptions (Slovic, 1987).

5.4 Reflection on Research Method and Further Areas of Study

The findings of this study are based on data collected from 476 online questionnaires collected between June and August, 2023. There are several revisions to the research method that could be improved upon in future research studies. One of the limitations of the study was related to sampling issues, more specifically biased demographic representations. This served as an acceptable limitation given that many social science studies have shown that biased demographic samples result from online survey non-probability sampling strategies and it was not intended for the observations of this study to be representative of the general population of southern Ontario. Further, a procedural bias in this study may have led to biases in the sample population of interest from social media (i.e., Twitter, Facebook, Reddit) groupings as the sample is likely not representative of the population of interest, i.e., campers and hikers in southern Ontario, within the realm of the broader general public and this can be further constrained by technological access to these sites. Sampling biases were also likely to have

occurred in this sample due to the self-selection and voluntary aspects of the survey itself, whereas participants with an inherent interest in the survey topic (i.e., professionals who work in the weather sector or weather enthusiasts) may have been more likely to take part in the survey than other possible participants. Adding to this, these participants are more likely to possess increased thunderstorm knowledge and weather saliency than the general targeted population (Stewart et al., 2012; Silver and Andrey, 2014). Future studies may benefit from the use of experience sampling methods consisting of randomly selected members of the general population, similar to methods used by Mills (2021) for winter storms and travel decisions. Additionally, future studies could focus on other outdoor groups that are commonly exposed to weather risks, such as golfers, beach-goers, boaters/fishers, large outdoor event attendees, and cyclists.

Reflecting on the use of hypothetical situations for the experimental aspects of this study, some critiques are also noted. Though some scholars note that behaviours observed in simulated real-world hazards events may provide a reasonable proxy for actual behavioural responses, other researchers point out that may not be true due to the lack of realized consequences in a hypothetical situation as compared to the real-world situations and people may be less risk-adverse in real life (Kox and Thicken, 2017; Weyrich, 2020c). Additionally, the importance of the outdoor activity was not evaluated in this study, which may explain why some individuals were more (or less) attentive to the activity and expressed differences in their likelihood to undergo desirable behavioural responses (Doksæter and Kolstø, 2016). Another important factor absent from the individualistic experiment research approach is the effects of social factors. For example, individual responses have been noted to be influenced by interactions with, and by the behaviours of others during tornadic hazard events (Silver, 2012). Future studies should take into account and test the relative importance of social factors in responses, in tandem with individual and exogenous factors, perhaps through observational or experience sampling methods. For example, a researcher could place themselves in a well-used hiking trail on specific days where thunderstorms are forecasted, and interview returning hikers if watches and/or warnings occur. Additionally, recall research methods could be carried out, whereas respondents are recruited using a similar sampling frame as this study, but those having had direct experiences of

thunderstorm events are selected for in-depth interviews of their experiences with risk information and their responses.

Critiques regarding the receiver characteristics used and the need for the inclusion of other potentially influential factors are also important to discuss. To begin with, this study only gauged negative emotional responses to past thunderstorm events based on fear, which is only one aspect of past experience. Additionally, positive past experiences may also be influential and should be considered in future works. In regard to other untested variables, trust, self-efficacy, response-efficacy, outcome expectancy, voluntariness, activity importance, and risk tolerance may also play significantly influential roles in the pathways of influence to behavioural responses and should be tested and/or controlled for in future works (Starr, 1969; Paton, 2003; Gatti and Brownlee, 2024; Keig et al., 2024).

In terms of the sampling techniques, future studies may benefit by the use of larger and more diverse samples that include members of the public who don't regularly spend time camping and hiking—exposing them to a variety of different situational contexts and hazard types. This would allow increased control, especially through testing the effects of less threatening hazards or inconvenient phenomena on responses, such as rainstorms, in comparison to thunderstorms, to determine if responses are based more on the fact that respondents will get wet during their activities. This can also apply to other temperature thresholds, such as high heat and humidity, which commonly occur in tandem with thunderstorm risk and have been shown to affect recreational activity tolerances (Rutty, 2014). Additionally, longer-onset events, such as heat waves should be given consideration, given the differences in the timing, saliency, and absence of some forms of risk information in Canada (i.e., heat waves). Lastly, post-event studies should take place to identify the effect that emergency alerts had on responses in conjunction with people's level of weather attentiveness, among other influential factors.

Future studies should test the influence of other message characteristics that may be important in people's attentional responses. Particular emphasis should be placed on the use of images in tandem with, or completely void of relevant textual information, on attentiveness, risk perceptions, and responses to environmental hazards; infographics have been noted as important in health communications (Lazard and Mackert, 2014). While infographics have been used for

communication of some environmental hazards, such as rip currents, empirical insights into their effectiveness on thunderstorms hazard responses is currently lacking. Selected graphics should showcase both the hazard(s) and the desired responses, using representative visuals of people in an outdoor recreational activity context that emphasizes optimism and a positive tone towards protective actions.

5.5 Implications of This Research

The results of this study provide several important implications for weather risk communications in Canada and abroad. Recommendations most applicable to the empirical results are noted first, followed secondly, by recommendations based off of responses from the sample and relevant findings in the literature that could be applicable. Most notably, these findings highlight that watches and warnings provide the intended meaning and thus produce high public responsiveness for outdoor recreationists. More specifically, people become increasingly attentive, perceive higher risk, and are highly likely to discontinue outdoor activities once official alerts, i.e., watches and warnings, are issued. While wireless emergency alerts may increase risk perceptions, warnings alone produce intended responses when taking part in outdoor hiking activities. Given the strong predictive relationships between the retrieval of a weather forecast and the likelihood of not going ahead with a planned hike, which is mediated by risk perceptions, safety could be further enhanced for outdoor recreational areas by easier accessibility or provisioning of weather forecasts, emphasizing thunderstorm risks, to recreationists. Based off of the relevant literature, this could come in the form of public advertisements reminding people who are planning to take part in these activities of the increased risks associated with thunderstorms, environmental cues associated with thunderstorm development, instructions to turn on notifications for and periodically check for official weather information updates, such as watches, and warnings, and provide information on where and how to safely seek shelter in the event of a thunderstorm. More specifically, the use of hand-out bulletins and/or signage at trailheads or park entrances that could use an internationally recognized and consistent system, similar to the *North American Public Avalanche Danger Scale* (Figure 21.). Additionally, advertisements could increase awareness for programs, such as the Canadian lightning danger map, which provides real-time updates of lightning activity across

Canada, outlining areas of increased risk of lightning strikes in the near future and the general movement of lightning hazards (ECCC, 2024b).

North American Public Avalanche Danger Scale			
Danger Level		Current Conditions	Know Before You Go
5 Extreme		Canadian Avalanche Bulletins www.avalanche.ca	☒ Does your group have the skills, knowledge and training to travel in avalanche terrain?
4 High		American Avalanche Advisories www.avalanche.org	☒ Are you carrying transceivers, shovels and probes?
3 Considerable		   	☒ Can you self-rescue? Do you have a plan?
2 Moderate			☒ Do you know the emergency number?
1 Low			☒ Have you checked the current avalanche bulletin and weather forecast?
☒ Have you checked out with someone?			
☒ Do you have any other route options?			
You control your own risk.			

Figure 21. Bulletin of the North American Public Avalanche Danger Scale (CORE, 2023).

Specific recommendations for Canada's NMHS Environment and Climate Change Canada and Alert Ready include:

- Provide an emphasis on the alerting aspects of Canada's current warning system, i.e., distinct alerting mechanisms and differences between watches and warnings, if the alerting system changes to become more linear and progressive in regards to hazard risks and informational needs. The distinct alerting system that occurs currently with official watches and warnings creates a salient distinction between forecasted hazards

and increasingly urgent threat levels that capture peoples attention. A progressive system may not provide the salient aspects and make people attentive, which is an important aspect in behavioural response intentions during short-notice hazard events, such as thunderstorms.

- Specific mentioning of the disruptive implications to outdoor recreational activities and recommended actions during the provisioning of thunderstorm forecasts and severe thunderstorm watches and warnings.
- Wireless Emergency Alerts should audibly distribute both the unique warning sound and script of the information included in the warning so that attention can be captured and maintained for a longer duration. The callout of the specific information instead of leaving it up to the individual to read through the message may also increase perceived risks and lead to a greater uptake of and response to the information for those who assess audible information best. Similar practices already occur during events through television and radio media using text-to-speech features. As noted on the Alert Ready website (Alert Ready, n.d.), “broadcasters may use text-to-speech software to create an audio version of an alert message”, but extensive work has not been done to integrate this feature into all compatible cellular devices.
- Wireless emergency alerts and warnings should provide an increased emphasis on visual elements, particularly infographics, that communicate the hazard, expected impacts, and recommended precautions. This is important because most people process visual information best, infographics capture attention well, people discern the meaning behind images and videos faster than verbal or written text, and they are considered helpful in the decision-making process (Lazard and Atkinson, 2015). Additionally, WEAs should emphasize the ‘extreme’ danger of the thunderstorm hazard, given that they only state that a severe thunderstorm warning has been issued, which may cause people to think that they are going to be impacted by a common severe thunderstorm, not an event with particularly extreme and dangerous hazards.
- Geovisualizations using cartographic elements, of the thunderstorm threat and expected arrival times in tandem with outdoor recreationists’ approximate location

should be provided in warnings and/or wireless emergency alerts to provide spatial context of the threat in regards to users' locations.

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Appendix A

Survey Questionnaire

Informed Consent

Into the Woods: Attentiveness to Weather Information During Outdoor Recreational Activity

Principal Investigator: Kyle Woods (*MES Candidate; Honors Bsc. Environmental Science*)

Faculty Advisor/Supervisors: Dr. Jean Andrey (*PhD; Department of Geography & Environmental Management*)

Faculty Advisor/Supervisor: Dr. Brian Mills (*PhD; Department of Geography & Environmental Management*)

You are invited to participate in this study to better understand how the public responds to information about thunderstorms while outdoors through a survey. The researcher is a University of Waterloo graduate student in the Department of Geography & Environmental Management working under the supervision of Dr. Jean Andrey and Dr. Brian Mills.

INFORMATION

Participants are invited to participate for questions on their use of different forms of weather communication during the spring and summer, their past experience with thunderstorms, and how they would perceive and respond to various weather communications about thunderstorms while they are hypothetically taking part in an outdoor hiking activity in southern Ontario. Participants will be randomly assigned to two different groups, where one group will be provided with weather information of a higher severity than the other for watches and warnings, respectively. There are no right or wrong answers. The survey will ask at the end for some

demographic information such as age, gender, and education. The study will take about 15 to 20 minutes to complete. Data from approximately 350 to 500 research participants of different ages (18+), genders and education levels will be collected for this study. The researchers are collecting this demographic information to compare the survey demographic makeup with southern Ontario and to understand the influence of demographic characteristics on weather attentiveness and weather salience.

ELIGIBILITY

For this study, the researchers are looking for participants who are adults that regularly engage in outdoor recreational activities, mainly hiking and camping in southern Ontario during the spring, summer, or fall. The researchers are looking for participants who meet these criteria as they are most at risk to hazards from thunderstorms in southern Ontario while engaging in outdoor recreational hiking activities. To be eligible to participate in this study you must meet three (3) criteria:

- Be 18 years or older
- Currently live in southern Ontario
- Been camping and hiking, at least once, during the spring, summer, or fall in the last two (2) years.

RISKS

As a result of your participation in this study you may be exposed to psychological and/or emotional risk(s), if you have previously been involved in a traumatic or scary incident as a result of severe weather. There may be risks due to the inclusion of questions that ask about your previous experience with thunderstorms, your behaviours to them, and how they made you feel. This is minimal risk research and the risk(s) to participants are considered to be short-term minor

risk(s). The following safeguards will be used to minimize any risks/discomforts: you can refuse to answer any part(s) of the questionnaire and you are free to discontinue the study at any time.

BENEFITS

Participants may feel a sense of satisfaction about improving our understanding of weather risk perceptions, safety, and communications. Further, the research will contribute to the body of literature/knowledge on weather attentiveness, risk perceptions, human-environment interactions, environmental hazard exposure reduction, and emergency management and reduction which informs weather communication approaches.

CONFIDENTIALITY

Your identity will be kept confidential. When results are reported, the confidentiality of your personal information data will be ensured to the absence of any direct identifying information, such as name(s), email addresses, or any other personal information. The data will be stored in a locked office on a password protected computer located at a home office.

- All survey answers and data provided will be kept for at least 2 years and will then be destroyed by the principal investigator.
- The anonymized data will be stored indefinitely and may be reanalyzed in the future as part of a separate project (i.e., secondary data analysis).
- While in transmission on the internet, the confidentiality of data cannot be guaranteed.
- The privacy and confidentiality of information submitted through the online survey software provider, Qualtrics, cannot be guaranteed. However, Qualtrics has implemented technical, administrative, and physical safeguards to protect the information provided via the services from loss, misuse, and unauthorized access, disclosure, alteration, or destruction.

- Only aggregate results will be published/presented.
- If you consent, quotations may be used in write-ups/presentations. Quotes will contain age and gender and will not contain information that allows you to be identified.

Please Note: We do not collect or use internet protocol (IP) addresses or other information which could link your participation to your computer or electronic device.

CONTACT

If you have questions about the study as a result of participating in this study you may contact the researcher, Kyle Woods at kwoods@uwaterloo.ca or his academic supervisors, Dr. Jean Andrey at jandrey@uwaterloo.ca and Dr. Brian Mills at bmills@uwaterloo.ca.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Board (REB #44484), If you have questions for the Board, contact the Office of Research Ethics, toll-free at 1-833-643-2379 (Canada and USA), 1519-888-4440, or reb@uwaterloo.ca.

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty. You have the right to refuse to answer any question(s) or skip questions that you do not wish to answer.

Due to the absence of identifiable information (i.e., name, phone number, email address) collected during the survey, if you withdraw from the study your data cannot be requested to be removed and/or destroyed.

FEEDBACK AND PUBLICATION

The results of this research might be published/presented in a thesis, course project report, book, journal article, conference presentation, and/or class presentation.

- The results of this research may be made available through Open Access resources. An
- executive summary of the findings from this study will be available by May 1st, 2024.
- You can request the executive summary by e-mailing kwoods@uwaterloo.ca using the subject line, "Executive Summary Request". The executive summary will be emailed to you by May 1st, 2024.

CONSENT

I have read and understand the above information. I have printed a copy of this form if desired. Please indicate whether you would like to participate in the study:

- ☐ Yes
- ☐ No

Please indicate whether you consent to the use of quotations from text-entry questions in the survey. When quotations from text-entry questions are used in the study data and write-up, they will be de-identified, but attribution may involve gender and/or age and education experience.

☐ I have read and CONSENT to the use of quotations from text entry questions. Continue to the survey

☐ I have read and DO NOT CONSENT to the use of quotations from text entry questions. Continue to the survey

By continuing to the survey, I agree to participate in the survey. By providing your consent, you are not waiving your legal rights or releasing the investigator(s) or involved institution from their legal and professional responsibilities. It is advised that you print or save this consent form and/or record the researcher(s) contact information in the case that you have any questions or concerns.

It is advised that you print or save this consent form and/or record the researcher contact information in the case that you have any questions or concerns.

Thank you in advance for your interest in this project.

Yours sincerely,

Kyle Woods (Bsc. MES Candidate)

Welcome Message: Thank you for participating in this University of Waterloo study examining thunderstorm activity during outdoor recreational activities. Please respond to the following questions as completely and accurately as possible. There are no right or wrong answers. Your identity will remain confidential.

Screening Questions

“Please answer the following questions to determine your eligibility to participate in this study”

1. Are you 18 years or older?
 - a. Yes
 - b. No
2. Do you currently live in Southern Ontario?
 - a. Yes
 - b. No
3. Have you gone camping and hiking, at least once, during the spring, summer, or fall in the last two years?
 - a. Yes
 - b. No

“You answered yes to all three questions, please proceed.”

- Pop-up message if all three are selected as a “yes”

“Since you did not answer ‘yes’ to all of the screening questions, you are not eligible to participate in this study. Thank you for your interest.”

- Participants automatically directed to this thank you message due to ineligibility criteria for participation

Section 1: Thunderstorm Knowledge and Interest

“Please review the following statements and choose the response that best describes your usual behaviour during the spring and summer months (May to September).”

For most of the questions in this section you will be asked to respond on a 5-point scale, indicating the frequency with which you do something or the level of your agreement with a statement.”

1. I take notice of changes that occur in the weather. (Weather Salience)
 - a. Never (1)
 - b. Seldom (2)
 - c. Sometimes (3)
 - d. Usually (4)
 - e. Always (5)
- OPEN-ENDED: What changes in the weather cause you concerns for safety? (Weather Salience – Environmental Cues)
2. I notice how the clouds look during various kinds of weather. (Weather Salience)
 - a. Never (1)
 - b. Seldom (2)
 - c. Sometimes (3)
 - d. Usually (4)
 - e. Always (5)
- OPEN-ENDED: Describe the clouds that you would associate with thunderstorms. (Weather Salience – Environmental Cues)
3. I plan my day around what the weather may bring. (Weather Salience)
 - a. Never (1)
 - b. Seldom (2)
 - c. Sometimes (3)
 - d. Usually (4)
 - e. Always (5)
4. I check the weather because I find it interesting. (Weather Salience)
 - a. Strongly Disagree (1)
 - b. Disagree (2)
 - c. Neither Agree nor Disagree (3)
 - d. Agree (4)
 - e. Strongly Agree (5)
5. I am familiar with weather patterns that indicate the possibility of thunderstorms. (Weather Salience)
 - a. Strongly Disagree (1)
 - b. Disagree (2)

- c. Neither Agree nor Disagree (3)
 - d. Agree (4)
 - e. Strongly Agree (5)
- 6. I check the weather more often when planning for outdoor recreational activities away from home. (Attentiveness)
 - a. Strongly Disagree (1)
 - b. Disagree (2)
 - c. Neither Agree nor Disagree (3)
 - d. Agree (4)
 - e. Strongly Agree (5)
- 7. I check the weather more often when I am taking part in outdoor recreational activities away from home. (Attentiveness)
 - a. Strongly Disagree (1)
 - b. Disagree (2)
 - c. Neither Agree nor Disagree (3)
 - d. Agree (4)
 - e. Strongly Agree (5)

Section 2- Weather Communication – Social and Environmental Cues

1. How often, during the spring and summer months, do you actively seek each of the following forms of weather communication. (Response options: Never, less than once a month, about once a week, several times a week, everyday): (Attentiveness)
 - a. Radio station(s)
 - b. Television/News Networks
 - c. Social Media (e.g., Twitter, Facebook, LinkedIn, etc.)
 - d. Websites (e.g., Environment Canada, The Weather Network)
 - e. Mobile Apps (e.g., the Weather Network App, WeatherCAN, default weather app)
 - f. Talk to other people (communication face-to-face or on the phone) (4)
 - g. Other (Please Specify)
2. If you are outdoors and taking part in recreational activities during the spring and summer months, what would be the best way to make weather alerts available to you? (communication media)
 - a. Telephone call

- b. Text message
 - c. Weather radio broadcast
 - d. Visual cell phone pop-up notification with sound
 - e. Other (Please specify)
- 3. Briefly explain your understanding of the difference between a thunderstorm watch and a warning.
OPEN_TEXT (Weather Salience)
- 4. Rate the danger level to you that is associated with each of the thunderstorm hazards below: (Response options: Very High, High, Moderate, Low, Very Low) (Weather Salience)
 - a. Lightning that strikes the ground
 - b. Damaging severe winds not associated with a tornado
 - c. Heavy Rain/Flash flooding
 - d. Hail large enough to damage cars
 - e. Tornado
- 5. The following conditions prompt me to pay greater attention to the weather. (Response Options: Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree). (Attentiveness)
 - a. Changing sky conditions
 - b. Hearing thunder
 - c. Seeing lightning that strikes the ground
 - d. Seeing precipitation (rain or hail)
 - e. Mention of severe thunderstorms in the forecast
 - f. Receiving an official severe thunderstorm watch
 - g. Receiving an official severe thunderstorm warning
 - h. Information from a friend or loved one
 - i. Other (Please Specify)

Section 3: Thunderstorm experience

“People experience thunderstorms throughout their life. Please think about your experiences with severe thunderstorms and indicate your level of agreement with the statements listed below (Response options: Strongly Disagree, Disagree, Neither Agree nor Disagree, Agree, Strongly Agree)

1. I have feared for my life due to a thunderstorm
2. I have feared for my loved ones due to a thunderstorm
3. I have worried about my home due to a thunderstorm
4. How much do you know about thunderstorm safety and preparedness?
 - a. Not at all knowledgeable
 - b. Not very knowledgeable
 - c. Somewhat knowledgeable
 - d. Very knowledgeable
 - e. Expert level of knowledge
5. To what extent have you searched for information about how thunderstorms form, the dangers they pose to safety, and/or precautions people should take for them?
 - a. Not at all
 - b. Very little
 - c. Somewhat
 - d. Quite a bit
 - e. A great deal
6. Briefly explain how you prepare for severe weather when planning for outdoor recreational activities away from your home in the spring and summer months? (OPEN TEXT)
7. Briefly explain what kind of messaging (both content of the message and how it is provided/delivered) you think would provide excellent weather safety at outdoor public spaces, such as campgrounds and beaches? (OPEN TEXT).

Section 4: Outdoor Activity Scenarios

“For this section, you will be presented with three scenarios. Each scenario includes details on the weather and your participation in summertime outdoor recreational activities away from your home.”

Scenario 1: “Imagine that you are camping in a tent close to your car at a provincial park campground. You are a several hour drive from your home and you are planning on spending the afternoon doing a 4-to-5-hour hike. A permanent park building containing a visitor centre and public washrooms is located a 10-minute walk from your campsite and the park is within the range of cellular tower signals with no issues with respect to phone connectivity. There are no park buildings on the hiking trail.

For several of the questions in this section you will be asked to respond on a scale that runs from 0 to 10. Please answer all other questions by selecting the response that most clearly reflects your thinking.”

1. How likely is it that you would check the weather forecast in the morning, before starting your hike that day? (Behavioural Intentions)
 - Response options: ratings on an 11-point scale from 0 = “I definitely would NOT check the forecast” to 10 = “I definitely WOULD check the forecast” (with response options 1-9 not labelled).

Scenario 1 (Continued): “It is the morning and, before starting the hike, you obtain (e.g., on your phone or through a posting at the visitor centre) the following thunderstorm forecast message for the area where you will be hiking:

Please review this information closely. You may refer back to this as needed for the next several questions:”



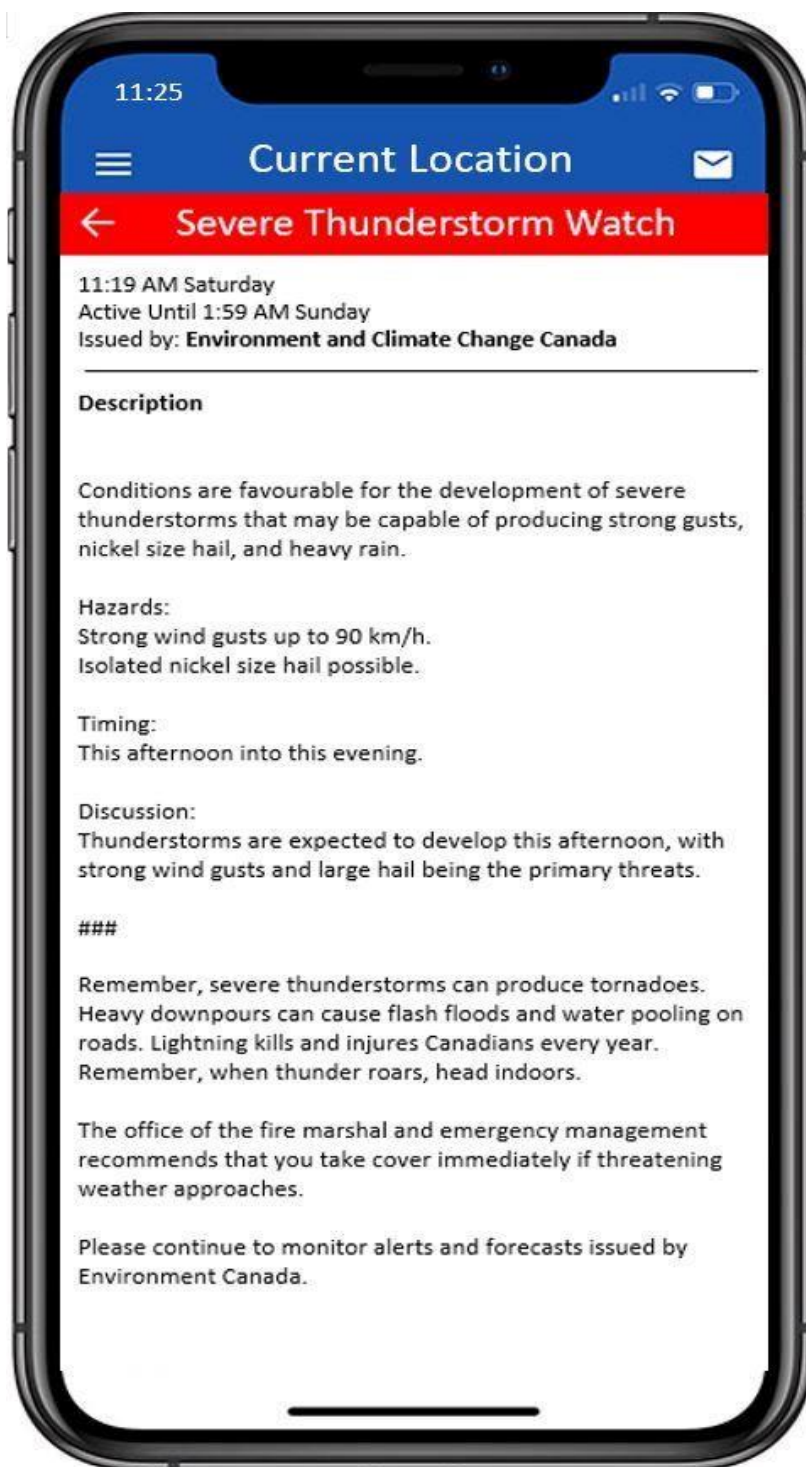
1. Please indicate the level of risk this scenario poses to your safety.
 - Response options: ratings on an 11-point scale from 0 = “NO risk” to 10 = “VERY HIGH risk” (with response options 1-9 not labelled). (Risk/Severity)
2. How likely is it that you would go ahead with the hike if you received this information? (Behavioural Intentions)
 - Response options: ratings on an 11-point scale from 0 = “I definitely would NOT do the hike” to 10 = “I definitely WOULD do the hike” (with response options 1-9 not labelled).
3. How likely is it that you would continue paying attention to the weather (e.g., checking radar, websites, social media, observing clouds, etc.) if you received this information? (Attentiveness)
 - Response options: ratings on an 11-point scale from 0 = “I definitely would NOT continue paying attention” to 10 = “I definitely WOULD continue paying attention”
4. How likely is it that you would seek out more information about the thunderstorm threat if you received this information? (Attentiveness)
 - Response options: ratings on an 11-point scale from 0 = “I definitely would NOT seek out more information” to 10 = “I definitely WOULD seek out more information” (with response options 1-9 not labelled).

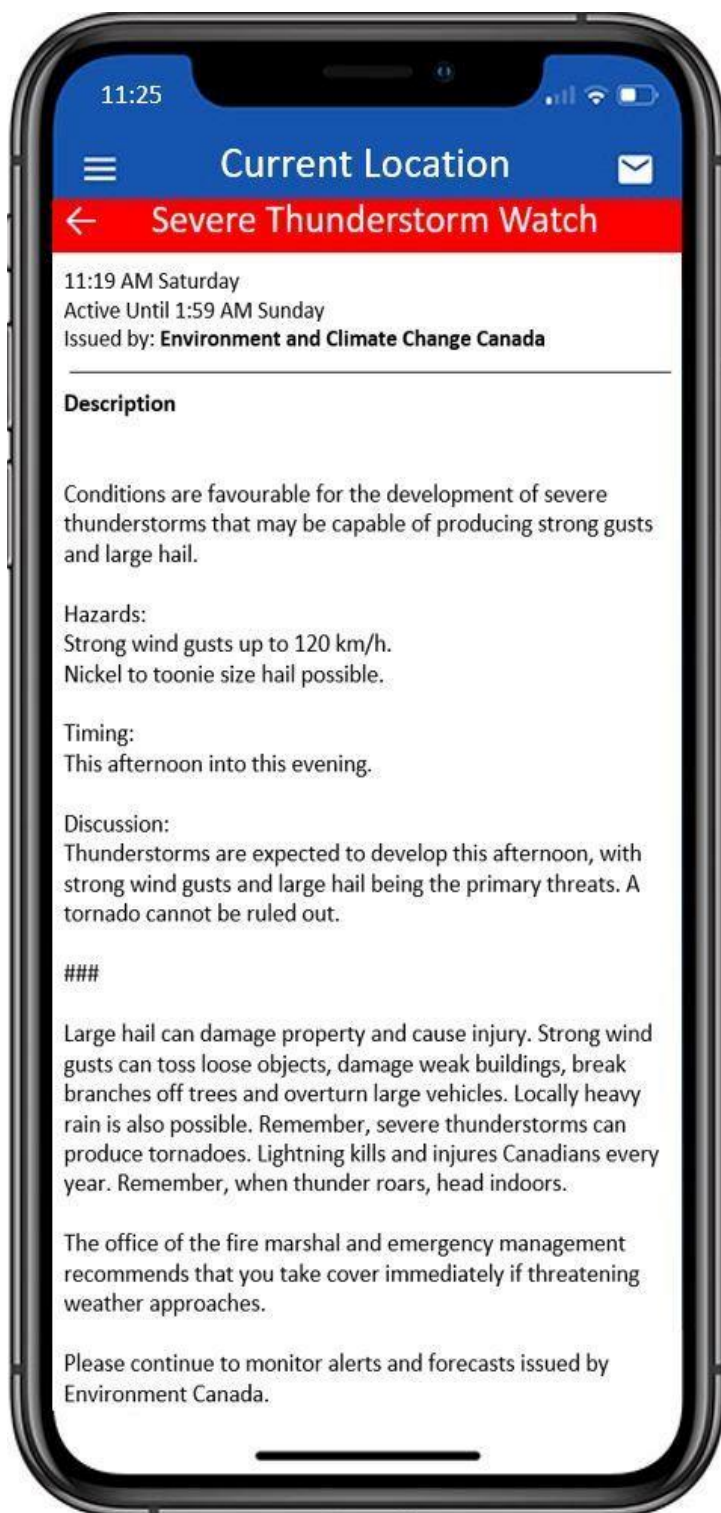
[SKIP to Q7 if answer = 0/Never]

5. If you were to seek out more information, what would be your main source? (communication media)
 - o Social Media (E.g., Twitter or Facebook) (1)
 - o Websites (E.g., Environment Canada, The Weather Network) (2)
 - o Mobile Apps (E.g., the Weather Network App, WeatherCAN, default weather app) (3)
 - o Talk to other people (communication face-to-face or on the phone) (4)
 - o Other (Please Specify) (5)
5. a) How often would you use the source to seek out more information about the thunderstorm threat?
 - Response options: ratings on an 11-point scale from 0 = “Never” to 10 = “Every few minutes”

5. b) Which additional sources of information would you use to seek out more information about the thunderstorm threat? (check all that apply)
- ☐ Social Media (e.g., Twitter or Facebook)
 - ☐ Websites (e.g., Environment Canada, The Weather Network)
 - ☐ Mobile Apps (e.g., the Weather Network App, WeatherCAN, default weather app)
 - ☐ Talk to other people (communication face-to-face or through cellphone from other individuals)
 - ☐ Other (Please Specify)
6. Given the scenario and forecast, what changes in your surroundings would you look for to know whether a thunderstorm might develop later that day? TEXT (Weather Salience – Environmental Cues)

Scenario 2: “In this scenario, you are now well into your hike and approximately 1 hour away from the campground and you obtain the following thunderstorm message on your phone:”





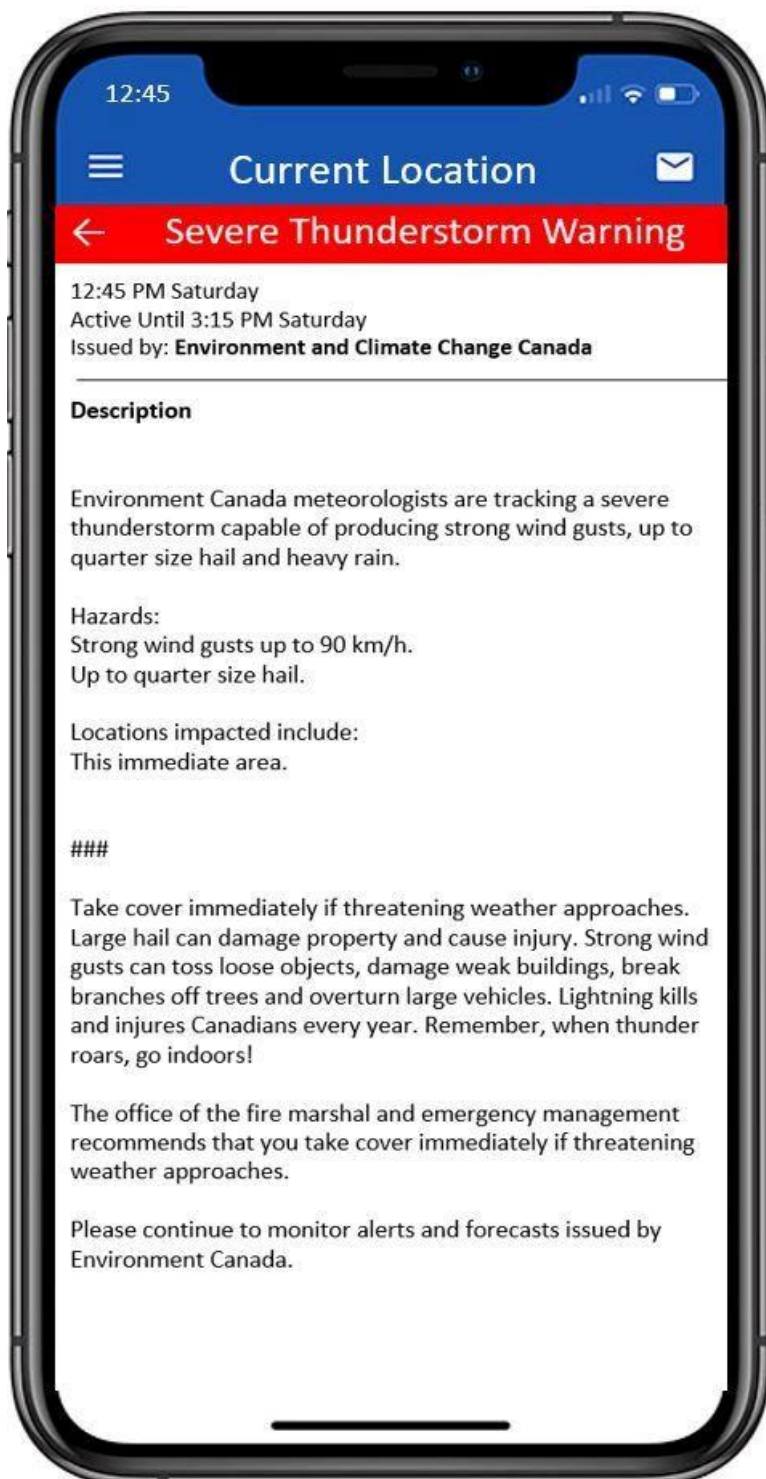
1. Please indicate the level of risk this scenario poses to your safety.
 - Response options: ratings on an 11-point scale from 0 = “NO risk” to 10 = “VERY HIGH risk” (with response options 1-9 not labelled). (Risk/Severity)
2. How likely is it that you would continue participating in your hike if you received this information? (Behavioural Intentions)
 - Response options: ratings on an 11-point scale from 0 = “I definitely would NOT continue doing the hike” to 10 = “I definitely WOULD continue doing the hike” (with response options 1-9 not labelled).
3. How likely is it that you would continue paying attention to the weather (e.g., checking radar, websites, social media, observing clouds, etc.) if you received this information? (Attentiveness)
 - Response options: ratings on an 11-point scale from 0 = “I definitely would NOT continue paying attention” to 10 = “I definitely WOULD continue paying attention”
4. How likely is it that you would seek out more information about the thunderstorm threat if you received this information. (Attentiveness)
 - Response options: ratings on an 11-point scale from 0 = “I definitely would NOT seek out more information” to 10 = “I definitely WOULD seek out more information” (with response options 1-9 not labelled).

[Skip to Q7 if answer = 0/Never]

5. If you were to seek out more information, what would be your main source? (Communication media)
 - o Social Media (E.g., Twitter or Facebook)
 - o Websites (E.g., Environment Canada, The Weather Network)
 - o Mobile Apps (E.g., the Weather Network App, WeatherCAN, default weather app)
 - o Talk to other people (communication face-to-face or on the phone)
 - o Other (Please Specify)
5. a) How often you would use the source to seek out more information about the thunderstorm threat?
 - Response options: ratings on an 11-point scale from 0 = “Never” to 10 = “Every few minutes”

5. b) Which additional sources of information would you use to seek out more information about the thunderstorm threat? (check all that apply)
- o Social Media (E.g., Twitter or Facebook)
 - o Websites (E.g., Environment Canada, The Weather Network)
 - o Mobile Apps (E.g., the Weather Network App, WeatherCAN, default weather app)
 - o Word of mouth (communication face-to-face from other individuals)
 - o Other (Please Specify)
6. How likely is it that you would take immediate action to protect yourself from the thunderstorm threat if you received this information in this scenario? (Behavioural intentions)
- Response options: Ratings on an 11-point scale from 0 = “I definitely would NOT immediately take protective action” to 10 = “I definitely WOULD take protective action” (with response options 1-9 not labelled).
7. Given this scenario, what protective actions would you take (remember that you are 1 hour from the campground)?
8. Given the scenario and watch message, what changes in your surroundings would you look for to know whether a thunderstorm may be developing? TEXT (Weather Salience – Environmental Cues)

Scenario 3: “In this scenario it has been approximately 1 hour after you received the previous message on your phone and you receive the following alert and following message on your phone. You are two hours from the campground”





1. Please indicate the level of risk this scenario poses to your safety.
 - Response options: ratings on an 11-point scale from 0 = “NO risk” to 10 = “VERY HIGH risk” (with response options 1-9 not labelled). (Risk/Severity)
2. How likely is it that you would continue participating in your hike if you received this information? (Behavioural Intentions)
 - Response options: ratings on an 11-point scale from 0 = “I definitely would NOT continue doing the hike” to 10 = “I definitely WOULD continue doing the hike” (with response options 1-9 not labelled).
3. How likely is it that you would continue paying attention to the weather (e.g., checking radar, websites, social media, observing clouds, etc.) if you received this information? (Attentiveness)
 - Response options: ratings on an 11-point scale from 0 = “I definitely would NOT continue paying attention” to 10 = “I definitely WOULD continue paying attention”
4. How likely is it that you would seek out more information about the thunderstorm threat if you received this information? (Attentiveness)
 - Response options: ratings on an 11-point scale from 0 = “I definitely would NOT seek out more information” to 10 = “I definitely WOULD seek out more information” (with response options 1-9 not labelled).

[SKIP to Q7 if answer 0/Never]

5. If you were to seek out more information, what would be your main source?
 - o Social Media (e.g., Twitter or Facebook)
 - o Websites (e.g., Environment Canada, The Weather Network)
 - o Mobile Apps (e.g., the Weather Network App, WeatherCAN, default weather app)
 - o Talk to other people (communication face-to-face or on the phone)
 - o Other (Please Specify)
5. a) How often you would use the source to seek out more information about the thunderstorm threat.
 - Response options: ratings on an 11-point scale from 0 = “Never” to 10 = “Every few minutes”

5. b) Which additional sources of information would you use to seek out more information about the thunderstorm threat? (check all that apply)
 - o Social Media (E.g., Twitter or Facebook)
 - o Websites (E.g., Environment Canada, The Weather Network)
 - o Mobile Apps (E.g., the Weather Network App, WeatherCAN, default weather app)
 - o Word of mouth (communication face-to-face from other individuals)
 - o Other (Please Specify)
6. How likely is it that you would take immediate action to protect yourself from the thunderstorm threat if you received this information in this scenario? (Behavioural intentions)
 - Response options: Ratings on an 11-point scale from 0 = “I definitely would NOT immediately take protective action” to 10 = “I definitely WOULD take protective action” (with response options 1-9 not labelled).
7. Given this scenario, what protective actions would you take (remember that you are several hours from the campground)?
8. Given the scenario and warning message, what changes in your surroundings would you look for to know whether a thunderstorm might soon occur? TEXT (Weather Salience – Environmental Cues)

Note: Watch (scenario 2) and warning (scenario 3) scenarios for common severe thunderstorm activity uses the same questions and statements, but different information on the phone messages.

Section 5 - Demographic Questions:

“For this section, you will be asked several questions about your age, gender identity, education experience, and Ontario residency. We are interested in collecting this information to compare our study demographic with the general population of Ontario.”

1. What year were you born? (e.g., 1967)
 - a. Year (TEXT)

- b. Rather not say
2. What gender do you most identify with?
- a. Man/Transman
 - b. Woman/Transwoman
 - c. Genderqueer/Gender non-conforming/Gender non-binary/Gender Fluid
 - d. Two-spirited
 - e. I prefer to self-define (OPEN TEXT)
 - f. Prefer not to say
3. I'm interested in your education and training experience. Please indicate which of the following you have completed courses in: (Check all that apply)
- a. High School/Secondary
 - b. Apprenticeship and other trades program(s)
 - c. College, CEGEP, or other non-university institution(s)
 - d. University
 - e. Rather not say
 - f. Other (please specify)
4. How long have you lived in southern Ontario?
- a. Less than 1 year
 - b. 1 to 5 years
 - c. 6 to 10 years
 - d. More than 10 years

Appendix B

Rationale for PLS-SEM Use

1. It allows for an easy-to-understand visualization of the proposed relationships between variables and supports the use of moderating and mediating variables on relationships in complex models (i.e., path models) to test theories. As Hair et al., (2019:12) explains, “Path models are diagrams used to visually display... relationships that are examined when SEM is applied”. Path models consist of the ‘structural model’ which shows relationships between constructs and the ‘measurement model’ which shows relationships between constructs and their indicator variables. The latter must be tested and confirmed to be made up of reliable and valid indicators before the structural model can be assessed.
2. PLS-SEM does not require normal distributions (i.e., it is non-parametric) or hierarchical components for testing relationships and also works under other SEM technique violations: multicollinearity within indicators and between explanatory variables, as well as erroneously omitted predictor variables (Hair et al., 2017).
3. PLS-SEM does not require variables to be measured using the same scale, instead acting as a composite-based SEM, method, whereas constructs are made up of equally weighted linear-assessed indicators.

Ethics Approval Form

UNIVERSITY OF WATERLOO

Notification of Ethics Clearance to Conduct Research with Human Participants

Principal Investigator: Jean Andrey (Geography and Environmental Management)

Student Investigator: Kyle Woods (Geography and Environmental Management)

Co-Investigator: Brian Mills (Geography and Environmental Management)

File #: 44484

Title: Attentiveness to Weather Information During Outdoor Recreational Activity

The Human Research Ethics Board is pleased to inform you this study has been reviewed and given ethics clearance.

Initial Approval Date: 06/02/23 (m/d/y)

University of Waterloo Research Ethics Boards are composed in accordance with, and carry out their functions and operate in a manner consistent with, the Institution's guidelines for research with human participants, the Tri-Council Policy Statement for the Ethical Conduct for Research Involving Humans (TCPS, 2nd edition), International Conference on Harmonization: Good Clinical Practice (ICH-GCP), the Ontario Personal Health Information Protection Act (PHIPA), the applicable laws and regulations of the province of Ontario. Both Boards are registered with the U.S. Department of Health and Human Services under the Federal Wide Assurance, FWA00021410, and IRB registration number IRB00002419 (HREB) and IRB00007409 (CREB).

This study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Expiry Date: 06/03/24 (m/d/y)

Multi-year research must be renewed at least once every 12 months unless a more frequent review has otherwise been specified. Studies will only be renewed if the renewal report is received and approved before the expiry date. Failure to submit renewal reports will result in the investigators being notified ethics clearance has been suspended and Research Finance being notified the ethics clearance is no longer valid.

Level of review: Delegated Review

Signed on behalf of the Human Research Ethics Board



Karen Pieters, Manager, Research Ethics, karen.pieters@uwaterloo.ca, 519-888-4567, ext. 41495

This above named study is to be conducted in accordance with the submitted application and the most recently approved versions of all supporting materials.

Social Media Groups Used for Recruitment

- Facebook: Thematic Facebook groups related to camping and hiking were primarily used. The approved Facebook groups included: "Camping in Ontario at its best", "Ontario Provincial Park Camping (unofficial)", "Ontario Camping, Hiking, and Kayaking", "Ontario Backcountry Camping", "Ontario Storm Reports", "ActiveDays: Ontario", "Hiking Ontario at its best", "Instant Weather App". Here, the survey was posted on the feed of these Facebook pages twice: The first initial posting and a follow-up posting several weeks after the initial posting.
- Twitter: A similar method was be used for twitter, whereas, a tweet was provided using a personal twitter profile and included the following hashtags: #OntarioParks, #OntarioCamping, #DiscoverOntario, #ExploreOntario, #Ontario.
- Reddit: The social media recruitment post on reddit was posted to the following threads: r/Ontario, r/CampingOntario, r/OntarioCamping, r/OntarioHiking, r/HikingCanada, r/ONProvincialPark, and r/OutdoorOntario.