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It's a dry heat: professional perspectives on extreme heat risk in Utah

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ABSTRACT

Heat waves are the deadliest weather-related hazard in the United States while also increasing in frequency, intensity, and duration. Population growth is also occurring in places most exposed to extreme heat. Current US National Weather Service (NWS) guidelines to issue heat alerts vary geographically and may not facilitate optimal heat risk communication. This study focuses on professionals' decision making and communication in the context of extreme heat risk in Utah, a state with historically low but increasing heat risk due to climate change, a growing population, and rising outdoor recreation visitation. We analyze the mental models of decision-makers responsible for forecasting, communicating, and managing heat risk in Utah using interviews with 32 weather forecasters, media broadcasters, and public officials including park managers. Results demonstrate that institutional norms have influenced how forecasters characterize extreme heat in the western region of the US. NWS heat alerts and tools are new and unfamiliar to many decision-makers, especially in areas of the state where previous criteria did not warrant alerts. Only 44% of participants from these areas were familiar with NWS heat alerts compared to 100% of participants from areas with a history of heat events. While experience with NWS heat alerts and tools varied widely among participants, 100% were familiar with heat protective behaviors. 94% stated they had personally experienced extreme heat and 66% stated that this experience influenced their decisions. Personal experience may be an effective means to communicate heat risk and promote adaptive practices. These insights may be generalizable to other settings where risk is changing and communication strategies are underdeveloped.

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risk communication; extreme heat; mental models; decision-making; communicators

Introduction

Heat is the deadliest weather-related hazard in the United States (Bernard and McGeehin 2004; Kalkstein and Sheridan 2007; NWS 2016; Borden and Cutter 2008). Over the past 30 years the U.S. has recorded 138 extreme heat deaths on average per year, a number that is considerably higher than floods (88), hurricanes (45), and tornadoes (68) (NWS 2016). Extreme heat events are increasing in frequency, intensity, and duration (Romero-Lankao et al. 2014; White-Newsome et al. 2011; Vose et al. 2017) More people are exposed to extreme heat because population growth is occurring in the most exposed places (Jones et al. 2015). This study examines perspectives of decision-makers responsible for planning and communicating about the risk of extreme

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heat in Utah, which is among the country's fastest growing states (US Census Bureau 2016) and an area of rising heat exposure associated with a warming climate and population growth, as well as rapidly rising outdoor recreation visitation (DeMille 2017; J. Lee 2017; University of Utah n.d.).

Despite the serious risk, heat risk perception is relatively understudied. Scholars emphasize that vulnerability is influenced by how one perceives risk (Grothmann and Patt 2005; Jonsson and Lundgren 2015; Slovic 1987; Wilhelmi and Hayden 2010; Zografos, Anguelovski, and Grigorova 2016), but few have systematically investigated extreme heat risk perception (Akompab et al. 2013; Howe et al. 2019; Kalkstein and Sheridan 2007; Sampson et al. 2013; Semenza et al. 2008; Sheridan 2007). In a recent national survey, 64% of Americans were worried about harm from extreme heat in their local area, more than other extreme weather hazards including drought, flooding, wildfires, and hurricanes (Leiserowitz et al. 2019). Howe and colleagues (Howe et al. 2019) found that heat risk perceptions were generally higher in states with a greater heat exposure and, at the local level, in neighborhoods with higher social vulnerability. In the same study, heat risk perception in Utah was generally lower than the national average (Howe et al. 2019).

The objective of this study was to determine how extreme heat is perceived and communicated by professionals in Utah to improve communication practices and reduce risk in future heat events. Professionals in this context are defined as expert stakeholders or decision-makers who communicate, measure, or protect others from risk or harm as part of their regular, paid work duties. In particular, this includes news reporters, weather forecasters, park managers and responders, and public officials. Documented extreme heat events demonstrate that perceptions and decisions about extreme heat are influenced by institutional and cultural norms (Poumadère et al. 2005; Klinenberg 2015). Heat-related illness and death are often preventable (CDC 2018) because heat-protective behaviors can be simple, quick, and affordable, although some behaviors—such as using air conditioning—are not equally accessible, exacerbating social vulnerability for some (Akompab et al. 2013). Despite the preventability of heat-related health consequences, people are frequently unable to promptly identify the onset of heat stroke or heat exhaustion symptoms before serious illness ensues (Harlan et al. 2014). For these reasons extreme heat has been called a "silent killer" (Mishra and Suar 2007; Poumadère et al. 2005; Klinenberg 2015). Some experts are exploring how to measure heat stress more accurately with new technologies and metrics (Kuras et al. 2017; H. Lee, Mayer, and Chen 2016; H. Lee, Holst, and Mayer 2013) but the techniques have not yet been widely used in communication strategies.

Little research has evaluated the effectiveness of current heat risk communication practices to increase awareness and mobilize adaptive strategies within the US (Hawkins, Brown, and Ferrell 2017). The National Weather Service (NWS) has initiated internal studies to evaluate the effectiveness of their current heat alert products (watches, warnings, and advisories) and acknowledges need for improvement (Hawkins, Brown, and Ferrell 2017). NWS guidelines for issuing heat alerts are written to be flexible to meet the needs of individual Weather Field Offices (WFOs), but experts at these offices generally recognize that this broad flexibility introduces challenges that create confusion among constituents (Hawkins, Brown, and Ferrell 2017). Most recently, the western region of the NWS has implemented a tool to evaluate heat wave potential in arid regions where traditional heat alert thresholds underrated the possibility of dangerous extreme heat. This tool is called Experimental HeatRisk and takes into account factors like climatology, local acclimatization, and timing and duration of the heat event in less humid yet still potentially deadly high desert climates (NWS n.d.). NWS forecasters in Utah started using this tool to measure when and how to issue heat alerts during the summer of 2017.

The few external studies that have examined the effectiveness of current NWS heat alert products indicate that warnings must meet specific conditions to elicit behavioral response from the general population. Warning messages must come from a credible source and contain information that is considered important to the population (National Research Council 2013). Likewise, simply hearing a warning does not mean a person will change their behavior (Kalkstein and Sheridan 2007; Lefevre et al. 2015; Sheridan 2007). If warnings are disseminated too often, people respond less due to the 'cry wolf' effect (Hawkins, Brown, and Ferrell 2017; Kalkstein and Sheridan 2007; LeClerc and Joslyn 2015). People implement protective behaviors less often when warnings trigger positive memories of hot summers (Lefevre et al. 2015). Also, cost constraints can limit a person's ability to implement strategies like air conditioning (Lefevre et al. 2015; Sheridan 2007).

Since heat risk communication is still not well understood, qualitative social research methods to gather detailed contextual knowledge may provide insight for future research. Mental models interviews provide a method to gather such information (Bruine de Bruin and Bostrom 2013; Morgan, Fischhoff, and Bostrom 2001; Morss et al. 2015; Slovic 1987). A mental model approach was used to evaluate NWS flash flood alerts in Boulder, Colorado by a set of companion studies (Lazrus et al. 2016; Morss et al. 2015). This example provides a framework to conduct a similar evaluation of NWS heat alerts in Utah. NWS heat alert practices in Utah were investigated in this manner with the following research question:

1. How do professionals (expert stakeholders and decision-makers responsible for heat risk messaging) characterize and make decisions regarding heat risks?

Based on the findings from this question, our objective is to identify knowledge gaps and misconceptions between NWS forecasters and their partners that can be addressed to improve local communication and response, and promote protective behaviors amongst community members. This study is the first to use a mental model approach to understand stakeholder decision-making about heat risk. Findings may improve NWS heat alerts by exposing communication problems and facilitating recommendations for successful warning response (Bruine de Bruin and Bostrom 2013; Morgan, Fischhoff, and Bostrom 2001; National Research Council 2013).

Methods and materials

This study followed a mental model approach to risk communication, which involves a structured set of open-ended interview questions to understand how individuals characterize a system. (Morgan, Fischhoff, and Bostrom 2001). Using this approach, we investigated professionals' perspectives and decisions within the heat risk communication and warning system by conducting structured interviews, thematically coding the interview responses, and analyzing the results to describe how participants characterize and make decisions in the context of heat risk. The mental models approach starts with development of a draft expert model from the literature, which subsequently serves to organize qualitative findings systematically after conducting interviews. This model represents what researchers expect to find. Emerging themes or concepts may then shed light on knowledge and communication gaps. In this study, we developed a draft expert model—the Extreme Heat Risk & Warning System Model (HRSM)—by applying the literature on heat risk and vulnerability (Wilhelmi and Hayden 2010) to a risk communication and warning system scenario (Lazrus et al. 2016; Morss et al. 2015) (see Supplemental Materials). We then used this model to develop interview questions and an initial set of thematic codes. This study focuses on the first two major steps in the mental models approach to risk communication; additional steps can be applied to create and test improved risk messages (see Supplemental Materials).

Sample

We conducted mental model interviews with 32 professionals from three different domains important for heat risk communication in Utah: six NWS forecasters, four media broadcasters,

Table 1. Characteristics of interview sample. Number of participants by profession, their geographic scale of professional responsibilities, and the location of their jurisdiction within Utah. Six National Weather Service experts who hold forecasting responsibilities were interviewed, along with four media broadcasters, and 22 officials from emergency management, public health, and parks professions. All forecasters and media broadcasters cover the majority or all of Utah, while public officials represent various levels of local and state government, and state and federal park agencies.

Sample Characteristics						
Professional Group	Scale of Responsibilities			Jurisdictional Location		
National Weather Service	State less 4 counties (WFO boundaries)			Statewide*		
Forecasters (3)						
Managers (3)						
Media Broadcasters	State			Statewide*		
Chief Meteorologists (2)						
Environment/Hazard Reporters (2)						
Public Officers						
Emergency Managers (9)	City (3)	County (4)	State (2)	South (2)	North (5)	Statewide (2)
Public Health Officials (6)	County (4)	Region (1)	State (1)	South (1)	North (4)	Statewide (1)
Parks Officials (7)	State (3)**	National (5)***		South (8)**		

NOTES:
*Office located in North.
**1 Official represented and managed 2 parks.
***Includes recreation areas and monuments.

and 22 public officials. Public officials consisted of professionals from three areas: emergency management (9), public health (6), and parks or protected areas (7). This sample represents key professions at different levels of government and geographic location throughout the state (Table 1).

Utah is located in the Intermountain West region of the US. The climate varies substantially within the state, with the most populated counties in the north located in a semiarid high elevation steppe that experiences warm to hot summers and cold winters. In 2017, the Salt Lake City metro area—the largest in the state—experienced its hottest summer to date on record, breaking the all-time high of 107° F with six days consecutively over 100° F and 11 days over 100° F overall (NOAA 2018).

The central and southern part of the state is more rural and includes areas of high desert hot-summer/cold-winter climate, in which several high-visitation national parks are located (including Arches, Canyonlands, Bryce Canyon, and Capitol Reef National Parks). The southwestern corner of the state, including the St. George metro area and Zion National Park, is the hottest region of the state with very hot summers and mild winters. St. George was the fastest-growing US metro area in 2017, illustrating how shifts in population are increasing exposure to extreme heat in this region (Davidson 2018). Rising outdoor recreation visitation also increases exposure in the region. For example, visitation to Zion National Park and Arches National Park has almost doubled over the past 20 and 25 years, respectively (National Park Service n.d.). Many visitors are from other states or countries that may not be acclimated to a hot arid climate (Leaver 2019; 2017; J. Lee 2017; University of Utah n.d.)

Southern Utah has a history of extreme heat events that have triggered NWS heat alerts, whereas northern Utah had its first heat alert, an Excessive Heat Advisory, in the summer of 2017 (Herzmann and Iowa State University n.d.). The NWS Salt Lake City Weather Field Office (SLC WFO) is responsible for issuing weather alerts for all counties in the state of Utah and the southwest corner of Wyoming, excluding the four easternmost counties of Utah. One media market covers the entire state, so all broadcasters interviewed are responsible for a large geographic area. For these reasons, we chose to interview professionals from different areas of Utah within the SLC WFO boundaries to adequately represent perspectives and communication practices in places with different levels of extreme heat exposure, experience, and responsibility.

Interviewees represented a wide variety of experience and expertise in their jobs. All six forecaster participants were employed as forecasters or managers at the NWS SLC WFO. Media broadcaster participants were either professional meteorologists or environment/hazards reporters employed at various news organizations, including local television and radio. All public officials worked in areas of emergency management, public health, or parks, and had job responsibilities related to either responding to extreme heat events or communicating such events and precautionary measures to the public directly or through other agencies. To protect the anonymity of the interviewees, we identify them exclusively by either their professional group, official type, or geographic location.

Data collection

Through a partnership with the NWS SLC WFO, we conducted criterion and snowball sampling to solicit interviews from in-house forecasters and managers with heat alert experience, and partners with whom the WFO regularly collaborates to communicate weather alerts. Direct contact information for various media professionals and public officials were obtained through this partnership. Organizations with whom the WFO did not have established collaborations were identified separately and then approached via phone or email in order to represent various levels of government, geographic location, and agency responsibilities. All interviewees were initially contacted no more than three times via phone or email to elicit participation and subsequent follow-up contacts were pursued to schedule appointments.

The interview protocol (see Supplemental Materials) was approved by the Utah State University Institutional Review Board under Protocol #8615. All interviews were conducted by the first author. The interviewer pre-tested the interview protocol through two practice interviews with relevant professionals and adjusted the protocol as indicated. These practice interviews were not included in the sample. Individual semi-structured mental model interviews were then conducted in July and August of 2017, several months after the Experimental HeatRisk tool was implemented at NWS-SLC. All interviews were audio-recorded with permission of the participant following informed consent and later transcribed (except one, for which detailed hand-written notes were taken). Audio-recorded interviews were transcribed either manually or using an automated online tool, (Bastié and Assens 2017), with subsequent editing for quality. Interviews lasted between 39 and 118 minutes (mean: 57 min) and were conducted in person.

In risk communication, mental models represent thought processes or beliefs about a risk or how the world works that guide decisions or actions regarding that risk and through which new information is filtered (Morgan, Fischhoff, and Bostrom 2001; Lazrus et al. 2016). Interviews attempt to capture everything that influences a participant's mental model to understand misconceptions and knowledge gaps. Without establishing any expectation of how their mental models should be structured, we asked how participants conceptualize extreme heat risk and about their and others' decisions about this hazard (Morgan, Fischhoff, and Bostrom 2001). The interview protocol started with an open-ended format that grew more specific as the interview advanced. This format elicits key concepts as the interview progresses without cueing or prompting the participant. Thus, in this study, the interviewer started with broad questions such as "tell me about extreme heat" and "tell me about extreme heat in Utah", and followed up with prompts to elaborate on concepts as they were mentioned. As the interview progressed, more specific concepts were introduced by the interviewer. Such concepts included influences on extreme heat exposure, effects of extreme heat, risks of extreme heat, and if any actions can be taken to prevent or reduce these risks. The interviewer then asked about participants' decisions during their most recent extreme heat alert or event experience, the specifics about how interviewees communicated the alert or event, and if they had ever seen or used the new

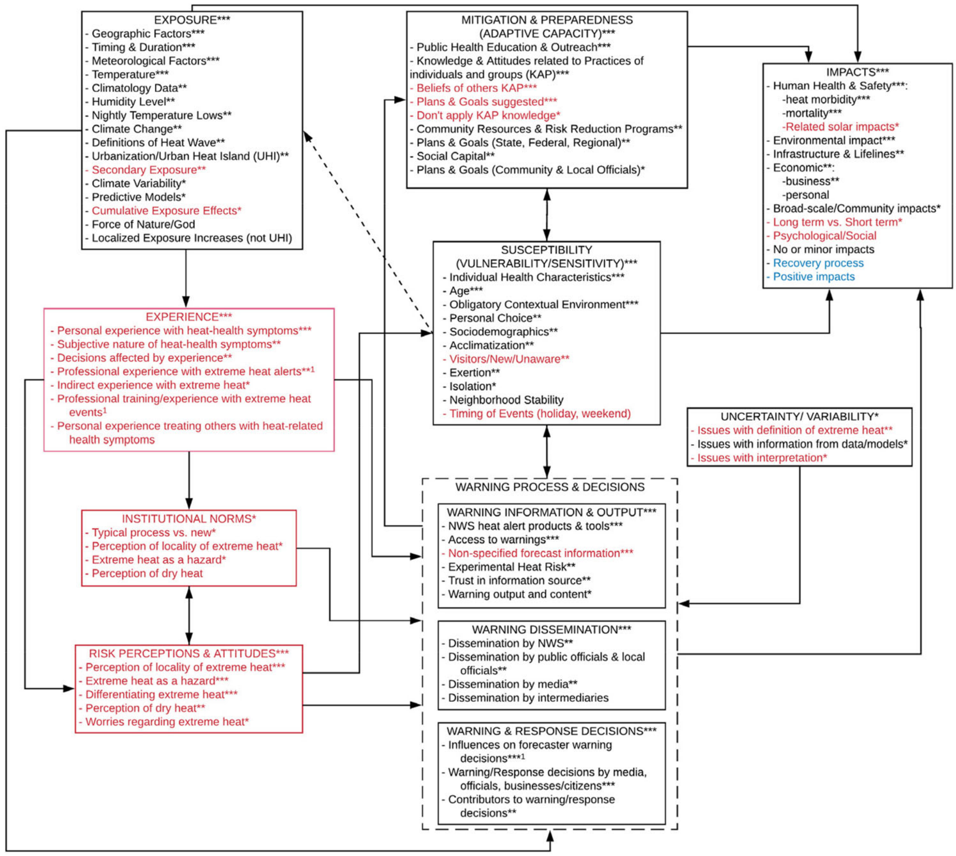

Figure 1. Extreme Heat Risk & Warning System Model created in this study (main concepts and sub-concepts). The 11 boxes with solid lines represent the main concepts analyzed in this study. The three boxes in red indicate new concepts that were added to the model from the interview results. Text in red indicates new sub-concepts. The dashed box contains the model concepts related to warning information and warning decisions. Asterisks indicate concepts mentioned by 25% - 49% (*), 50% - 89% (**), 90 – 100% (***) of interviewees. No asterisk indicates concepts that were mentioned by less than 25% of interviewees. Concepts in blue were not mentioned in the interviews at all. [1]indicates percentage was calculated according to the subset of interviewees who were asked these questions. Forecasters' previous experience issuing heat alerts was originally coded under Warning Process & Decisions.

Experimental HeatRisk tool described above. Interviewees were also asked to participate in ranking activities to understand how they characterize heat risk and practices to reduce this risk.

Coding, model development, and data analysis

We used the draft HRSM referenced above as the basis for creating the interview protocol and developing an initial set of thematic codes to analyze the interview data. We considered the entirety of the interview as the unit of analysis. A coding scheme allows unstructured data to be categorized systematically and allows for comparison between groups. This coding scheme was used to code all 32 interviews using ATLAS.ti software with a codebook containing definitions and examples for each code. When themes emerged from the data that were not in the original HRSM, these concepts were added as new or revised codes in the coding scheme and were incorporated into the HRSM. The finalized HRSM consolidates 112 codes, 19 code groups, and 9 broad code families, and represents the overall, collective mental model for this system (Figure 1). This procedure integrated perspectives and ideas from different professionals with varying expertise into the analysis and expanded the current expert view on heat risk in general.

Table 2. Thematic code mention totals by code group and interviewee type. The overall view of main concepts coded is described here by how many interviewees mentioned the concept, including its sub-codes, within each interviewee type starting with the professional groups: forecasters (F), media broadcaster (M), and public officials (O); and then broken down by jurisdictional location: north (N), south (S), and state-wide (SW). The 22 public officials' mentions are then broken down by the type of agency: emergency management (EM), public health (H), and parks (P). Boxes are shaded to represent zero members of that group mentioned the concept (white) to all group members mentioned the concept (dark grey). Most main concepts were mentioned by the majority of interviewee groups. Few participants mentioned the psychological impacts of extreme heat and no participants mentioned recovery from extreme heat events.

	Professional group			Jurisdictional location			Public official type		
Code group	F n = 6	M n = 4	O n = 22	N n = 9	S n = 10	SW n = 13	EM n = 9	H n = 6	P n = 7
Exposure	6	4	22	9	10	13	9	6	7
Experience	6	3	22	9	10	12	9	6	7
Affects decisions	5	4	18	7	9	11	6	6	6
Impacts	6	4	22	9	10	13	9	6	7
Economic Impacts	3	1	16	7	7	6	7	4	5
Health Impacts	6	4	22	9	10	13	9	6	7
Psychological Impacts	0	0	4	3	1	0	2	1	1
Recovery Impacts	0	0	0	0	0	0	0	0	0
Sensitivity	6	4	22	9	10	13	9	6	7
Vulnerability	6	4	22	9	10	13	9	6	7
Adaptive Capacity	6	4	21	8	10	13	9	5	7
Plans & Goals	6	3	21	8	10	12	9	5	7
Knowledge, Attitudes, Practices	6	4	22	9	10	13	9	6	7
Perceptions	6	4	22	9	10	13	9	6	7
Institutional Norms	6	3	12	5	7	9	3	4	5
Uncertainty	6	3	15	7	7	10	6	4	5
Warning Info & Process	6	4	22	9	10	13	9	6	7
Warning Decisions	6	4	21	8	10	13	9	5	7
Warning Dissemination	6	4	19	7	10	11	7	5	7

The same coder (the first author) coded all interviews in a randomized order between the different professional types. Codes were revised, created, or consolidated until saturation of themes was reached after coding the majority of the interviews, at which point the coding scheme was finalized and used to update the HRSM. A second coder evaluated the reliability of the coding scheme by coding three interviews randomly selected from each professional group. Interrater reliability was calculated based on the number of codes mentioned in each interview. The mean Cohen's kappa value was 0.84, which is within the range of acceptable values for this type of coding (Krippendorff 2004; Neuendorf 2002). Cohen's kappa was calculated for each code using ReCal2 (Freelon, n.d.) and for each interview group using R packages 'lpSolve' (Berkelaar and others 2015) and 'irr' (Gamer, Lemon, and Puspendra 2012).

Interview coding results were analyzed qualitatively to identify overarching themes, and specific quotes were selected to feature these broad themes. Results were also analyzed quantitatively to characterize what major concepts were and were not described by participants. Certain codes were sub-coded to calculate percentages of agreement and disagreement with certain concepts. Since the coding scheme is hierarchal, coding results were also examined at the broader level of code families, where subcategory codes were included in the general code family. These results were then compared between the three professional groups and their geographic location. Coding results of the three public official types were also compared across emergency management, public health, and parks officials.

Concepts mentioned in the ranking activities were standardized across all interviews by creating a separate codebook for the ranking questions. The ranking data were used to calculate the average ranking of the most common risks of extreme heat for each concept and its standard deviation. Counts were calculated according to the frequency of mentions. This means that concepts that were ranked separately by participants but consolidated into one code counted as additional rankings for the corresponding code to which they belonged. In this part of the analysis, the unit was each standardized concept-mention. Hence, counts could exceed the total number of interviewees (n = 32). This process was repeated to rank the most serious risks of extreme heat, and most effective heat risk-reduction practices. All codebooks used to analyze the data are available from the authors upon request.

Results

Overall themes

Three major themes emerged from the interviews: the role of personal experience with extreme heat, institutional norms regarding the risk, and risk perceptions and attitudes. These themes form important components of professionals' mental models around heat risk. Figure 1 depicts the combination of the HRSM mental model initially developed based on an analysis of relevant literature with changes that reflect these major themes from the interview results. In addition to these new themes, most existing concepts in the model were reflected in the interview results, including the role of uncertainty in forecasts, the warning decision-making process, characteristics of heat exposure, heat impacts, mitigation and preparedness, and variation in heat vulnerability. Table 2 summarizes the thematic coding results by the main themes in the model, illustrating how often participant groups mentioned certain themes. We detail each of the major new themes below.

Personal experience

Professionals had a wide range of experience with extreme heat alerts but 94% (n = 30) of participants stated they had personally experienced extreme heat and 66% said their experience, whether personal or indirect, affected their decisions and response. One park official said

> It can be very humbling. It can be very scary. It's an educational experience. There have been times when I did not prepare before I went out. And when I say prepare I mean making sure that my body was in good shape before I even left the car, that I felt as though I was teetering on going from heat exhaustion to shutting down. And alone, on a day that just so happened to be that my radio battery was dead … I've had a couple of scary events that there are times now when it's just like, 'eh, no, I'm not going out.' It's sobering.

Overall, there was less experience with official heat alerts in northern Utah amongst public officials (44%, n = 4) while there was a greater use and understanding of heat alerts by officials in southern Utah (100%, n = 10) where they happen more regularly. Some officials in northern Utah confused heat warnings with Red Flag Warnings which indicate hazardous fire weather, a secondary effect of extreme heat.

Institutional norms and trust

Institutional norms were discussed by all six forecasters, who explained that NWS had recently redefined their view of extreme heat in arid high desert regions, which previously had not been viewed as a high priority risk because few areas historically reached conventional humidity and temperature thresholds. One forecaster stated

> We had this criteria to issue heat products that was completely unreasonable for our climatology … . Forecasters had a perception that heat just wasn't a problem. 'It's hot here in the summer, no big deal.' So, if you were to ask a forecaster what … sort of high impact weather does their forecast area have, they would probably talk about … weather related to fires, they'd talk about winter storms, whatever their local climatology has but they'd almost never talk about heat. So, this is all to say it was something that just wasn't much in our consciousness as an agency from the perspective of the West.

At the NWS, shifts in institutional norms about the dangers of dry heat were associated with the newly deployed Experimental HeatRisk tool (launched during the summer of 2017 when the interviews were conducted). The tool was designed to forecast local-level extreme heat risk more

Table 3. Sub-code mention totals for 'Warning: Info & Process" code group by interviewee type. Sub-code mention totals are listed by how many interviewees mentioned the sub-concept including within professional group (forecasters [F], media broadcaster [M], and public officials [O]), by jurisdictional location (north [N], south [S], and state-wide [SW]), and type of public official's agency (emergency management [EM], public health [H], and parks [P]; n = 22 public officials). Boxes are shaded to represent zero members of that group mentioned the concept (white) to all group members mentioned the concept (dark grey). Most participants spoke about accessing warning information, including NWS products and tools, but few public officials were familiar with the Experimental HeatRisk tool. Few public officials could recall specific content of official heat alerts, all of whom were from the southern region of Utah where heat alerts are historically more prevalent.

CODE	PROFESSIONAL GROUP			JURISDICTIONAL LOCATION			PUBLIC OFFICIAL TYPE		
WARNING: INFO & PROCESS	F n = 6	M n = 4	O n = 22	N n = 9	S n = 10	SW n = 13	EM n = 9	H n = 6	P n = 7
General/Other	0	0	6	2	3	1	3	1	2
Access to warning information	6	4	21	8	10	13	8	6	7
Content of official alerts	3	2	6	0	6	5	2	1	3
Experimental HeatRisk Tool	6	4	9	4	4	11	5	1	3
Not heard of Exp. HeatRisk Tool	0	0	15	6	6	3	6	5	4
Non-specified forecast info	4	4	21	9	9	11	9	6	6
NWS products and tools	6	4	20	7	10	13	9	4	7
Trust information source or not	6	3	16	5	9	11	7	2	7

accurately in the western US context. 68% of public officials had not heard of the Experimental HeatRisk tool, while all forecasters and media participants were aware of it.

Although most participants mentioned warning information, decisions, and dissemination, some aspects of the heat risk warning and communication systems in Utah were new and unfamiliar to many participants (Table 3). Unlike some other hazards, forecasters consistently spoke of having high confidence in extreme heat forecasts days in advance because of the nature of this hazard. Uncertainty for them related more to the specifics of how to interpret the forecasts from the Experimental HeatRisk tool as some results do not coincide with the contextual knowledge they have of the area. Public officials and media broadcasters were not concerned about the validity of the information from NWS heat alerts but brought up concerns about how to interpret some of the information contained in the products including the new HeatRisk tool, and, more commonly, questions were voiced about how to define extreme heat and the relativity of the term.

Most public officials (91%, n = 20) talked about NWS products and tools in general, but 95% also relied on forecast and alert information for which they could not remember the source. Regardless of experience with heat alerts, most officials stated that they trust NWS forecasts and warning products (68%, n = 15) and respond accordingly. One emergency manager said:

> If NWS is telling us 'Yes, this is the way it is.' OK. We take it as Bible truth. If we're hearing it maybe through some other [source]–they're not weather experts necessarily. 'Appreciate the heads up.' Now, let's confirm it through NOAA or NWS or somebody like that.

Media broadcasters did not tend to prioritize NWS products as consistently as public officials (n = 2, 50%). Contrasting media comments included

> You didn't ask this but frankly we don't put a whole lot of credence into heat advisories… And the reason is 'It's hot and dry, don't be stupid.'
>
> – Media (Interview #14)
>
> We have a direct feed from NWS. So, the moment it's issued I'm issuing it on social media and it's top priority in the news.
>
> – Media (Interview #20)

Broadcasters who placed less emphasis on heat alerts cited personal perceptions of heat or the time constraints that require them to prioritize news to what is most relevant and important to the majority of people in the state. One media broadcaster said their viewers' lack of concern about extreme heat influences its lower prioritization in order to avoid negative viewer response.

Risk perceptions and attitudes

Risk perceptions and attitudes about extreme heat were also spoken about often on a personal level with most officials recognizing that it is a deadly hazard that must be taken seriously, but it was not the only hazard they have to be concerned about. One emergency manager said:

> So, we face lots of risks in Utah. Some more frequent than others. And it's important that we know all the risks that we face. But I think this is one that is overlooked somewhat. Somewhat. We talk a lot about winter storms and we talk a lot about earthquake … But as far as heat, it's just probably a risk that we don't think of very often. So, one that maybe we're not prepared for enough.

Although extreme heat may not receive as much attention as other hazards, officials and media broadcasters were aware of its risks and impacts. Officials often defined extreme heat by its impacts instead of the physical phenomena that create extreme heat exposure. Regardless of their meteorological knowledge, officials and media broadcasters tended to know the basic signs, symptoms, and treatments for heat illnesses, and prevention and preparedness tips for extreme heat (knowledge that was also shared by forecasters).

Participants emphasized that extreme heat is largely underestimated as a serious health threat by the general population. One park official said:

> I think that it is a hard one for people to wrap their mind around. They've been hot before, you know. I'm not sure that understanding of that it can truly kill. Or, maybe [it's] that 'it can't happen to me' mentality.

Participants emphasized that many people are largely unaware of how dangerous heat can be and how quickly someone's health can be affected. To address this mentality, 97% ($n = 31$) emphasized educating the public on the basic signs, symptoms, treatments, and prevention/preparedness tips to reduce extreme heat risks in Utah, yet 38% said that people, including themselves, do not always apply the knowledge they have to their personal situation:

> I mean knowledge is one thing but taking the action on it is completely different. I think we are all pretty knowledgeable of the things that we're supposed to do when it's hot out. But a lot of us probably don't do them.
>
> – Forecaster

Knowledge or capacity gaps

Knowledge gaps revolved around awareness of official heat alerts, the Experimental HeatRisk tool, technicalities of how extreme heat occurs, and how to define extreme heat. Although some officials may not have completely understood what causes extreme heat, they were attentive to its individual and broader impacts, susceptible populations during extreme heat situations, and the appropriate measures to respond. Public officials, particularly in the north, were less aware of excessive heat alerts and relied on standard operating procedures in their general emergency plans to respond to this hazard as a large event. Participants expressed interest in creating more coordinated efforts to educate the public and establish community plans to reduce heat risks but reported constraints to accomplishing such goals. 31% ($n = 10$) of participants had never seen anything about what to do during an extreme heat event in any form of media. Furthermore, although 47% ($n = 15$) of participants mentioned ways that their local government and community have implemented plans or initiatives during extreme heat, when asked if they had ever received anything from their local government about what to do during an extreme heat event, 81% said no.

Ranking risks and mitigation practices

Interviewees were asked to list extreme heat risks in Utah, sort them from most common to least common, and then re-sort them from most serious to least serious. A similar question asked participants to list what individuals can do to reduce their own risks to extreme heat and rank them from most effective to least effective. Heat risk rankings varied amongst participants (Table 4).

Table 4. Average rankings for extreme heat risks. Interviewees ranked extreme heat risks according to what they considered as the most common (1) to least common, and most serious (1) to least serious. Heat risks mentioned more than 5 times are listed. Counts were calculated according to the frequency of mentions: concepts ranked separately by participants but consolidated into one code counted as additional rankings for the corresponding code to which they belonged. Hence, counts could exceed the total number of interviewees (n = 32). Lower means indicate each concept was ranked as more common or more serious. Bolded values indicate means with standard deviations less than 2.0 and italicized less than 1.0. "Heat exhaustion or heat stroke," and "dehydration" were mentioned the most. On average, "dehydration" was ranked as one of the most common risks while "heat mortality" was strongly agreed upon as the most serious risk of extreme heat. "Children locked in cars" was ranked as one of the most serious risks with high agreement but this risk was mentioned less often. Concept definitions are available upon request.

Average Rankings of Extreme Heat Risks

	Most Common			Most Serious		
CONCEPT	mean	s.d.	count	mean	s.d.	count
Heat Exhaustion or Heat Stroke	3.7	1.8	40	**2.5**	**1.3**	40
Dehydration	**2.3**	**1.1**	15	4.7	1.9	15
Heat mortality	4.9	2.1	12	***1.3***	***0.5***	12
Elderly	3.0	2.0	11	3.2	1.8	11
Health Impacts – General	2.6	2.2	10	2.7	2.1	10
Wildlife	3.3	1.7	10	4.7	2.2	10
Individual Health Characteristics	4.1	1.8	10	3.2	2.2	10
Infrastructure	5.2	2.7	10	3.9	2.1	10
Heat Symptoms/Injuries – Other	3.3	1.7	9	3.8	1.5	9
Young children & infants	3.0	2.4	8	3.0	2.0	8
Pets	4.6	2.0	8	4.9	2.4	8
Water accessibility	**2.0**	**1.3**	6	5.2	1.8	6
Children locked in cars	2.5	2.3	6	***1.3***	***0.5***	6
Wildfire	3.8	1.5	6	3.8	1.5	6
Sociodemographics	4.5	3.7	6	4.3	3.2	6
Discomfort/Fatigue	**2.0**	**1.2**	5	5.8	3.3	5
Pets locked in cars	2.6	2.1	5	2.8	2.5	5
Heat morbidity	**2.8**	**1.8**	5	**2.2**	**1.1**	5
Domestic Plants & Animals	3.4	1.5	5	5.4	1.1	5
Psychological/Social Impacts	3.4	2.6	5	6.0	1.6	5
Situational: Voluntary Exposure	3.8	3.6	5	3.8	2.4	5
Vehicle damage/diminishment	4.2	1.3	5	5.6	1.1	5
Secondary hazards	5.8	2.4	5	4.8	3.1	5

NOTES:
Bold indicates lowest means with s.d. < 2.0
Italics indicates s.d. < 1.0

On average, discomfort/fatigue, dehydration, water accessibility, and heat morbidity were considered the most common risks while heat exhaustion/heat stroke, heat mortality, heat morbidity, and children being locked in cars were ranked the most serious. Heat risk reduction rankings had a higher agreement among participants (Table 5). Recognizing and treating the signs and symptoms of heat exhaustion and heat stroke, planning, avoiding the hottest time of the day, awareness, and hydration were ranked the most effective practice on average with very similar means and standard deviations. When asked what action was the most effective to reduce extreme heat risk, hydration and awareness had the most votes for the entire sample while differences existed between public officials' and forecasters' top ranked practices (Figure 2).

Discussion

Several key findings emerge from these results. First, institutional norms at NWS on how to characterize dry heat in high desert regions influenced communication practices. Efforts to change these norms were underway, although they faced internal inertia. Second, personal experience with extreme heat among professionals is an important factor in their decision making. Third, while it appears that professionals are well aware of extreme heat risks, experience with heat alerts and responses were geographically dependent, due to regional climate variation and variation in NWS institutional norms regarding heat alert practices.

Table 5. Average rankings for heat risk reduction practices. Interviewees ranked heat risk reduction practices from most effective (1) to least effective. Practices mentioned more than 5 times are listed. Counts were calculated by the frequency of mentions meaning all items consolidated into each code were counted within each participant's ranking. Hence counts can exceed the total number of interviewees (n = 32). Lower means indicate a practice was ranked as more effective. "Hydration" was mentioned the most while knowing how to recognize and treat the signs and symptoms of heat stroke and heat exhaustion was considered on average to be the most effective practice to reduce extreme heat risk. Concept definitions are available upon request.

Heat Risk Reduction Rankings

	Most Effective Practices		
CONCEPT	mean	s.d.	count
Hydration	**2.5**	**1.2**	26
Awareness	**2.4**	**1.5**	16
Avoid hottest time of day	**2.4**	**1.0**	15
Lightweight/Light-colored clothing	4.4	1.1	14
Avoid the heat	3.9	3.2	13
Recognize & Treat signs/symptoms of heat exhaustion/stroke	**2.2**	**1.2**	12
Preparedness	3.5	2.5	11
Planning	**2.3**	**1.3**	9
Social capital	4.2	1.4	9
Know your limitations	3.4	1.6	7
Eat proper food	3.6	1.4	7
Health choices	2.8	1.3	5
Find/Stay in the shade	3.4	1.9	5
Protect	3.6	2.7	5

NOTES:
Bold indicates lowest means with s.d. < 2.0.

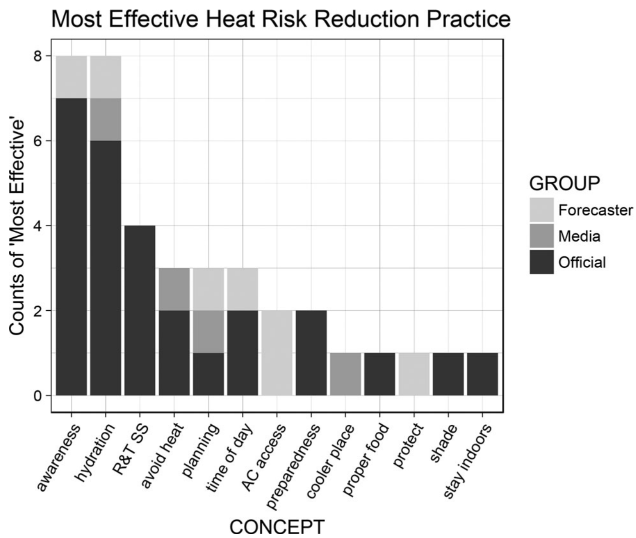

Figure 2. Top ranked most effective practices by professional group. When participants were asked which of the practices they listed were most effective in reducing extreme heat risk, these practices were selected. More officials ranked awareness as number one but forecaster and media votes gave hydration and awareness the same amount of number one votes overall.

Shifting NWS perspectives

While planning this project we were unaware that NWS had begun to address the institutional norms regarding extreme heat through the western regional office. By collaborating with the SLC WFO, we became aware that the regional office had trained WFOs in several western states to implement the Experimental HeatRisk tool in summer 2017. Forecasters have experienced a cultural shift within the agency to recognize and communicate about the dangers of dry heat in this region. Prior to implementing Experimental HeatRisk, although guidelines for heat products were flexible to adjust to each WFO (Hawkins, Brown, and Ferrell 2017), guidelines tended to not incorporate findings in other areas of science—like public health—that inform how to measure heat risk in differing climates. Hence, the health dangers of extreme heat in non-humid regions were historically overlooked in the forecasting process. This created an institutional culture that hot weather in high desert regions, like northern Utah, was not perceived to be a major risk. This perspective appeared to be shifting at the regional level within the agency: NWS began to incorporate other variables like local climatology, duration of the event, acclimatization, and cumulative effects of high nightly lows into their warning decisions. These factors can gauge the seriousness of extreme heat more accurately in these locations previously considered to be less dangerous. However, some forecasters mentioned that other professional colleagues question the importance and validity of acknowledging more frequent excessive heat events and maintain their prior opinion that high temperatures in arid regions with a higher elevation are not a major risk. A continued shift in the agency's perspectives on the dangers of dry heat will be necessary to successfully elevate awareness of extreme heat risks not only among the public but among professionals with whom they partner.

In general, we found that the public officials responsible for disseminating and responding to heat alerts trust NWS's heat alert products. Although public officials pay attention to general forecasts and are trained to respond in emergency situations regardless of the issuance of an NWS alert, officials may be less prepared to plan for an extreme heat event if an alert is not issued. This suggests that the institutional norms at NWS regarding heat alert criteria may have substantial cascading effects on heat impacts among the general population. If heat alert practices inaccurately reflect risk in high desert regions, then populations in these areas may be more vulnerable. These results support the heat risk research community's call to acknowledge all factors that exacerbate personal heat exposure to subsequently plan and prepare accordingly to minimize illness and death (Kuras et al. 2017).

As heat waves continue to become more severe, frequent, longer, and affect more people, it is important to measure changes in risk accurately to help officials be prepared to mitigate and respond accordingly to these events in the future. Investigating how NWS and their partners might adjust their definitions and response plans under a warming climate would be helpful in this process. Although not mentioned specifically by NWS forecasters, it is possible that the observed and/or projected increase in severity and frequency of heat waves also influenced NWS administrators to adapt their definitions.

Experience as a communication tool

Participants noted that they believed the public underestimated the health risks of heat in Utah, which is reflected in recent national survey estimates (Howe et al. 2019). Furthermore, risk perceptions of the public within the state did not appear to reflect experiences among stakeholders or patterns of where previous heat warnings have been issued: for example, the population of southwestern Washington County was estimated to have similar risk perceptions to that of Salt Lake County in the north (Howe et al. 2019), despite the higher number of hot days and associated heat alert products issued in Washington County.

Previous research has found conflicting results about the influence of personal experience on behavior, which tend to be dependent on the hazard and how experience is measured (Demuth et al. 2016; Mishra and Mazumdar 2015; Palm and Hodgson 1992; Scolobig, De Marchi, and Borga 2012; Sharma and Patt 2012; Wei, Su, and Liu 2013; Weinstein 1989; Zaalberg et al. 2009; Silver and Andrey 2014). Some scholars have emphasized the importance of acknowledging *how* experience influences behavior and what other variables mediate behavior instead of asking *if* it occurs or not (Demuth et al. 2016; Lindell and Perry 2012; Sharma and Patt 2012; Siegrist and Gutscher 2008; Wachinger et al. 2013; Zaalberg et al. 2009). Research specific to extreme heat acknowledges that if warnings trigger positive memories of hot summers, people implement protective behaviors less (Lefevre et al. 2015). This finding then prompts the question of whether *negative* memories could promote more appropriate response. Our results found that the majority of professionals in the sample stated that their personal and indirect experience with extreme heat encouraged them to implement protective actions and promote the seriousness of extreme heat. Appropriately activating memories of heat health symptoms may encourage people to take precautions and promote others to do the same. This strategy, which could be tested in a future experimental study, need not trigger extreme experiences as a scare tactic but simply help people remember how they felt, tell them what the experience means for their health, and encourage them to act to avoid the same consequences in the current heat event.

Consistency in awareness but geographic differences in responses

Professionals in Utah were aware of the short- and long-term impacts of extreme heat and how to mitigate or respond to these impacts. They recognized extreme heat as a serious danger but believed that a large proportion of the Utah population and its visitors substantially underestimate this hazard. Following up with the next step in the mental models approach—conducting the same interviews with members of the public—would be useful to address any communication gaps between professionals and members of the public. It is possible that the majority acknowledge the seriousness of the hazard but other constraints make it difficult for some to apply their knowledge. Identifying those constraints and what concepts people do not understand would help professionals know what is most important to include in their outreach initiatives and warning messages.

While professionals in Utah were aware of extreme heat and its impacts, experience responding to NWS alerts and extreme heat events was limited to professionals in the southern region. This is partly because, until the most recent changes through the Experimental HeatRisk tool occurred, the northern area of the state never reached the established criteria for a heat alert. Now that these criteria have been adjusted for the climatology and acclimatization of the area, alerts are more likely to be issued and professionals will accrue experience planning and responding to these events. The recent implementation of this tool and its implications for future NWS heat alerts makes it difficult to measure its impact on officials' current communication practices when they are still unfamiliar or unaware of the new system. A follow-up study on this area in several years would be informative to describe how professionals view, communicate, and respond to extreme heat when they have more experience on which to draw.

Generalizability and limitations

This study has several limitations. First, while our sampling method attempted to represent professionals responsible for forecasting, communicating, and managing heat risk in Utah, we used a partial snowball sampling method that may have excluded professionals not recommended by participants or included in our initial criterion sample. We interviewed different numbers of stakeholders across our three groups, so our ability to represent these groups at large may vary depending on the number of participants recruited.

Results of this study may be generalizable to other areas where heat risks are underestimated and particularly where heat exposure has been historically low overall but is currently increasing. These results may also be helpful in areas where professionals seek to improve overall perceptions of the dangers of extreme heat. Likewise, areas with similar high desert climatology or similar concerns about high visitation to public places during heat events may use these results to address challenges to incorporating effective heat risk messaging. Findings may be applicable to areas with other slow developing or less visible hazards (e.g. prolonged drought).

Conclusions

Extreme heat is seen as a serious but relatively underemphasized risk among professionals in Utah. While experience with NWS heat alerts and tools varied among participants, all were familiar with heat protective behaviors. Personal experience with extreme heat was consistently emphasized as an important motivator of behaviors to respond to extreme heat. As such, personal experience may be an effective theme with which to communicate heat risk and promote adaptive practices.

Our results also show that institutional norms have influenced how forecasters characterize extreme heat in this region. Extreme heat risk communication has historically been focused in the communities and parks of southern Utah where previous NWS thresholds were met. Officials and media broadcasters in northern Utah recognized the risks of extreme heat but had less experience responding to official alerts. Official heat alerts will likely become more common in northern Utah, where the majority of the population lives, due to the new NWS criteria and a warming climate. The new NWS criteria are helping to shift NWS professionals' perspectives on extreme heat in high desert arid regions like Utah and thereby provide more accurate warning system for these areas. Professionals in areas similar to Utah may use these results to support concerns about heat exposure and explore possible areas of miscommunication and needs for education in their own jurisdictions to improve their own planning, warning, and communication strategies for heat waves.

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