GLOBAL ASPECT
Vol.7 No.2 Dec. 2017
APEC Research Center for Typhoon and Society
11F., No.97, Sec.1, Roosevelt Rd., Taipei, 10093, Taiwan
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An Exploratory Examination Of the Impact of Uncertainty on Forecast Data Preference

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Introduction

Currently, in the United States, the weather community is moving toward a system of providing weather forecast information in a context that better conveys the degree of forecaster uncertainty. A number of efforts are underway to enhance the public's understanding of severe weather threats (American Meteorological Society, 2008). Initiatives such as the National Oceanic and Atmospheric Administration's Weather Ready Nation are designed to strengthen community preparation, mitigation, and response to weather hazards (https://www.weather.gov/wrn/). According to Novak (2008), significant gains have been made in understanding the use of probabilistic information in weather forecasts, however, additional research is needed to better understand the added value of its use for emergency managers.

In the United States, considerable attention has been given to the idea of changing how weather forecast information is shared, especially regarding how forecaster uncertainty is incorporated with additional probabilistic information when presented to the public. In contemplating the possibility of how probabilistic information will impact the public, it is important to gain a better understanding of the social and psychological factors that impact individuals' perceptions of uncertainty and risk, and their interpretation of that information. This research explores the role of uncertainty information for American emergency managers and their preference for working with probabilistic information. Focusing on better understanding the decision-making processes of emergency managers could give impactful insights for improvements in decision support tools.

Previous literature suggests probabilistic information can still create confusion and be misinterpreted by experts and non-experts (Gigerenzer et. al., 2005), however, more recent research by Morss et al. (2010) found that citizens in the United States successfully interpreted various types of weather forecasts and then used this information to make well-informed decisions. Kox et al. (2015) examined German emergency responders' (e.g., firefighters, police officers, and civil servants) understanding of and confidence in weather forecasts and warnings using probabilistic information. Results showed the emergency responders had an "appreciation" for the uncertainty in the forecasts, but did not identify a single probability threshold they could use for their decision-making. Nevertheless, they were still more likely to avoid making decision with low probability forecasts.

Emergency managers are required to intake forecast information, process it, and make effective and efficient decisions based on it. Part of this process involves deciphering, digesting, and repackaging uncertainty information, which is often presented in a number of ways. Previous research has highlighted the importance of *numeracy, need for cognition, and need for closure* as factors that impact decision making under uncertainty. Numeracy is defined as the ability to comprehend, use, and attach meaning to numbers, and is often referred to as quantitative literacy (Nelson et. al., 2008). Bodemer and Gaissmaier (2014) found numeracy can play an important role in risk perception. Specifically, individuals with lower levels of numeracy were more greatly influenced by message framing than those with a high level of numeracy. As Brust-Renck et al., (2014) asserts: "The complexity of numerical information about risk places demands on people that they are not prepared to meet." Thus, in order to better communicate risk numerically, it is important to identify whether an individual will be able to grasp the meaning behind the numbers presented. While there are different ways to assess numeracy, this research focused on subjective numeracy. The self-report scale used to assess subjective numeracy allows participants to report their perceived ability to perform mathematical tasks, and their preference for working with numerical information over textual information. The subjective numeracy scale measures perceptions of ability rather than actual ability (Fagerlin et. al., 2007) and has been well-validated (Zikmund-Fisher et. al., 2007).

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In addition to numeracy skills, previous psychological research suggests *need for cognition* can also help understand the decision-making process. *Need for cognition* is defined as a tendency to engage in and enjoy effortful cognitive activity (Cacioppo & Petty, 1982), and has been shown to affect behavior in problem-solving and decision-making (Furnham & Thorne, 2013). It is important to note that a higher need for cognition does not necessarily imply better decision making, "those with higher need for cognition are less likely to rely on superficial cues such as question wording when making decisions" (Carnevale & Lerner, 2011).

Similar to *need for cognition*, *need for closure* is another psychological concept that can help elucidate the decision-making process during times of uncertainty. *Need for closure* is defined as a motivation or desire for definitive knowledge on some issue or for a firm answer to a question, and an aversion to ambiguity (Webster & Kruglanski, 1994). Individuals who have a higher need for closure tend to process less information before committing to a judgment, and are more likely to generate fewer competing hypotheses to account for available information. In other words, as compared to individuals who are low in their need for closure, those who are higher in need for closure are more likely to make hasty decisions after considering less information in an effort to arrive at a decision in an uncertain context.

Taken together, previous research suggests that examining individuals' perceived numeracy abilities, need for cognition, and need for closure should shed light on how uncertainty information is processed and then used to make decisions. The present research examines these variables among a small sample of American emergency managers in an effort to understand how they utilize prototypical probabilistic forecast information in their decision-making.

Methodology

This research is part of a larger study and was conducted in partnership with scientists at the Hazardous Weather Testbed housed in NOAA's National Severe Storms Laboratory (NSSL) in Norman, Oklahoma during the Spring of 2016 and 2017. The study was designed, in part, to assess the needs of weather professionals as well as understand how emergency managers make decisions. All study participants volunteered to participate, and the Testbed procedures involved exposure to both "canned" severe convective weather scenarios (displaced, real-time weather events that had previously occurred in the United States) and "real time" severe convective weather scenarios that were happening in the United States at the time of the study. Participants were asked to "work" each scenario by performing their regular routines as emergency managers (e.g., choosing when to sound tornado sirens, close roads or schools, or cancel upcoming or ongoing events). Further, while working each scenario, participants were asked to rely heavily on the prototypical probabilistic information that was provided to them to make their decisions.

A mixed-methods approach was used in both 2016 and 2017, utilizing both a quantitative questionnaire prior to exposing participants to the weather scenarios and focus group interviews after each scenario. The 2016 sample consisted of seven emergency managers and their responses to the *Need for Closure, Need for Cognition*, and the *Subjective Numeracy Scales*. The 2017 sample consisted of six emergency managers, but these participants only responded to the *Need for Cognition and Subjective Numeracy Scales*. The majority of participants were seasoned professionals with at least three years of experience, but most had over 10 years of experience. The majority of the sample worked for a government agency within the Southwestern and Midwestern states in the United States. Participants completed the questionnaire prior to their exposure to the severe weather scenarios, and focus group interviews were conducted after the questionnaire (prior to the weather cases), and after participants "worked" each weather scenario.

Results

1. Numeracy

The *Subjective Numeracy Scale* is comprised of two components: perceived mathematical ability (Cronbach's α = .96), and preference for numerical over textual information (Cronbach's α = .70). Both subscales contain four items measured on 6-point Likert scales. Across both samples, participants self-reported a high ability for working with numerical information, M = 4.63, SD = 1.37, N = 13. While the sample reported a high numerical ability, their preference for working with numerical information over text is even higher, M= 5.09, SD = 0.74, N =13. Even though participants reported slightly lower perceived abilities for working with numbers (e.g., calculating a 15% tip), when considering all numeracy items together, this sample of emergency managers reported "very good" numerical literacy, M = 4.86, SD = 0.90, N = 13.

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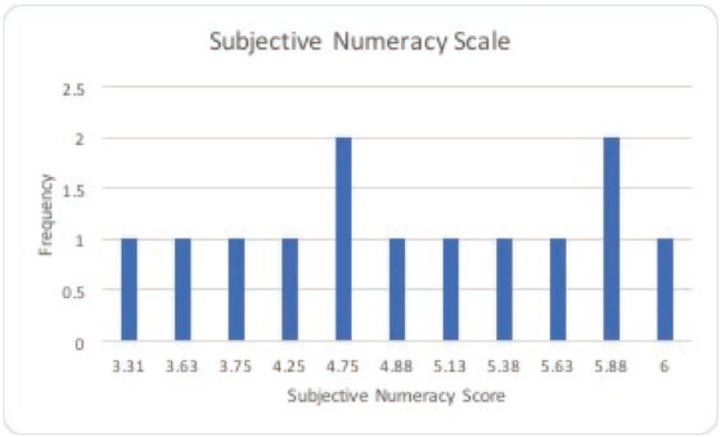

2. Need for Cognition

The *Need for Cognition* scale consists of 18 items (Cronbach's α = .88) measured on 5-point Likert scales. Across both samples, participants reported a high *need for cognition*, *M* = 3.67, *SD* = 0.64, *N* = 13. Given the amount of information emergency managers are responsible for processing during emergency situations, it is not surprising that, on average, they enjoy thinking.

3. Need for Closure

While both subjective numeracy and need for cognition were administered to the entire sample, only seven participants (i.e., the 2016 sample) completed the *Need for Closure* scale. The *Need for Closure* scale consists of 16 items (Cronbach's α = .77) measured on 6-point Likert scales. To address careless responding, there are two "lie items" that are used to filter out participants. No participants surpassed the threshold for exclusion; all participants were included in the analysis. Participants reported a fairly low *need for closure*, *M* = 3.05, *SD* = 0.56, *n* = 7. This is not surprising given the weight of the decisions they are forced to make on a daily basis; it is important for them to consider all possibilities before making decisions that impact so many other people's lives. However, a larger sample is needed to more adequately examine this construct.

Discussion

This research examined the impact of uncertainty on emergency managers' preference for forecast information. *Subjective numeracy, need for cognition*, and *need for closure* each address a component of dealing with an uncertain weather forecast. This sample of emergency managers has shown a high preference for working with numbers, even higher than their perceived ability to use numerical information. This suggests that a transition to probabilistic information may not be met with as much discomfort or resistance as some might expect, especially had the numeracy measure shown lower abilities. Since participants prefer using numerical information, the high *need for cognition* scores coupled with that preference may indicate that emergency managers would in fact prefer receiving more numerical or probabilistic forecast information because they prefer working with numbers and engaging in effortful cognitive activity. Several emergency managers in the sample expressed they have very small teams, but a

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variety of responsibilities. With a heavy workload, working with numbers might be more appealing to emergency managers. This possibility should be explored in future work. Finally, our sample reported having a relatively low *need for closure*. While the sample size is very small, emergency managers showed a desire to have multiple sources of information; most likely to gather additional information before making a decision, since their decisions can affect the safety and survival of their constituents.

These findings suggest that this sample of emergency managers are comfortable with uncertainty in general, evidence by their low *need for closure*. Participants enjoy thinking deeply about complex information, suggested by the high *need for cognition*. Additionally, they are comfortable with receiving and working with numerical information, indicated by their high self-reported numeracy skills. This could imply that there is less need to infer context or emotional cues that can occur with textual information. Taken together, these preferences could be a direct result of needing to gather as much information as possible before making a decision, since their decisions can affect the safety and survival of their constituents.

One limitation in this exploratory analysis is the small sample size. The goal is to continue this research and gather additional data on emergency manager decision-making with a larger variety of both emergency managers and locations and communities they serve. A larger sample size would allow more generalizable insights into decision-making components using forecast uncertainty information.

Subjective Numeracy Scale (SNS) Items Adapted From Fagerlin et al. 2007

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Item	Response Options	Cronbach's α
SNS Ability Subscale		.955
How good are you at working with fractions?	*Not at all good* to *Extremely good*	
How good are you at working with percentages?	*Not at all good* to *Extremely good*	
How good are you at calculating a 15% tip?	*Not at all good* to *Extremely good*	
How good are you at figuring out how much a shirt will cost if it is 25% off?	*Not at all good* to *Extremely good*	
SNS Preference Subscale		.698
When reading the newspaper, how **helpful** do you find tables and graphs that are parts of a story?	*Not at all helpful* to *Extremely helpful*	
When people tell you the chance of something happening, do you prefer that they use **words** ("it rarely happens") or **numbers** ("there's a 1% chance")?	*Always prefer words* to *Always prefer numbers*	
When you hear a weather forecast, do you prefer predictions using **percentages** (e.g., "there will be a 20% chance of rain today") or predictions using only **words** (e.g., "there is a small chance of rain today")? [reverse coded]	*Always prefer percentages* to *Always prefer words*	
How **often** do you find numerical information to be useful?	*Never* to *Very often*	
Overall Scale		.864

Note. All responses given on a scale of 1 to 6.

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