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Biases and Heuristics in Tornado Warning Response

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Abstract

A wide body of literature across numerous academic disciplines describes the difficulty people face when attempting to accurately formulate judgements based upon presented information. Doing so requires a keen ability to formulate independent and unbiased decisions despite uncertainties that might be present. Decision making is of utmost importance to professionals and end-users across the weather enterprise. Thus, there is a foundational relationship between cognition, behavioral psychology, decision support services, risk management, and meteorology. This paper aims to inform the connection between social science and meteorology by determining if there is evidence of cognitive biases and heuristics in tornado warning response. Topics analyzed include the Gambler Fallacy and the Hot-Hand Fallacy in relation to how individuals responded to experimental tornado situations. Statistical analyzes were performed to explore the degree to which these fallacies were present within the study cohort. Furthermore, a discussion about this research's significance to the weather enterprise—as well as society as a whole—will be addressed.

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1. INTRODUCTION

In the presence of alternative choices, our inner judgements oftentimes skew perceptions of reality. It is in these instances that the brain subconsciously resorts to over simplifications in order to make decisions upon processed information (Willingham 2001). Such actions are known across cognitive psychology as biases and heuristics. Behavioral scientists define cognitive biases and heuristics as the brain's ability to generalize complicated information into an easier to understand form (Willingham 2001). Thus, biases and heuristics are subconsciously engrained into our daily lives, but can lead to oversimplifications and falsities in decision making.

Two biases and heuristics serve as the backbone to this research due to their innate societal applications: The Gambler and Hot Hand Fallacy. Though fundamentally opposite in nature, this paper reveals that such biases and heuristics influence perception of weather risk. The Gambler Fallacy is the incorrect belief that events tend to neutralize over time (Chen et al. 2016). The Hot Hand Fallacy, on the other hand, is best conceptualized as a "winning streak". It is the belief that past events will continue into the infinitesimal future (Green and Zwiebel 2014). These fallacies, though widely present in our everyday lives, lack comprehensive research—especially, in a meteorological context (Croson and Sundali 2005).

In order to determine the degree to which these biases and heuristics influence tornado warning response, data collected by Klockow et al. (2013) was analyzed. Results indicate that Gambler and Hot Hand fallacies affect public perception of tornado risk. Further, it was concluded that the way in which humans make decisions is complex and not fully understood. These findings reflect upon diverse communication and education needs in the twenty-first century weather enterprise. Social science research within meteorology, moreover, is the bridge further enhancing the conversation initialized via these results. Thus, this paper ultimately demonstrates the need for such research in understanding biases and heuristics involved in tornado warning response.

2. DATA AND METHODOLOGY

Data used in support of this research was based upon information collected by Klockow et al. (2013). Klockow et al. (2013) analyzed public's perception of probabilistic forecasts[1] via experimental tornado situations. Participants in the study (n = 2,804) partook in essentially a computer game where each individual was in charge of monitoring one of four fictitious airport locations for the threat of tornadoes. These individuals ranged in age from 18 to 89, represented all 50 states, and were chosen via a third-party surveying company using census-balanced data. Ninety-six graphics were randomly presented to each individual. Graphics varied in terms of their airport location, forecast type (probabilistic or deterministic[2]), forecast length (long-term or short-term), and color scheme (continuous, divergent, and qualitative). Participants viewed each image and decided if actions were needed in order to protect their airport from the fictitious tornado. Figure 1 is an example graphic displaying a short-term deterministic forecast (see Appendix I for figures). In each of the 96 decision trials, if participants believed the fictitious tornado would strike their airports, users selected a "Protect" option on the computer interface.

On the other hand, if participants felt confident that the tornado would safely pass their designated airports, a "Do Not Protect" option was selected.

Data from Klockow et al. (2013) was quantitatively analyzed, via original Python scripts, in order to determine if parameters such as forecast type (deterministic or probabilistic) and gender influence beliefs concerning weather risk. It is through such findings that a discussion— pertaining to cognitive biases and heuristics in tornado warning response—exists.

[1] Probabilistic forecasts are ones in which numerical values (i.e. probabilities) are presented as a way to convey weather risk for a specific geographic region. For an example of a probabilistic forecast, please see Figure 2 in Appendix I

[2] Deterministic forecasts are ones in which polygons are used as a way to present weather risk to the public. All individuals residing within the polygon are said to be under the same level of risk. Please see Figure 1 in Appendix I for an example of a deterministic forecast.

3. RESULTS

3.1 Overall tendency for protective action from the 96 experimental tornado situations

Figure 3 (see Appendix I) displays the probability of an individual choosing to protect their airport after a pattern (String) of 3 to 10 consecutive tornado events. Such events are featured along the x-axis. The mean (red dashed line) represents the average likelihood that individuals elected to protect their airports. For these reasons, the mean is defined as the Average Response Tendency (ART). Evidence of the Gambler and Hot Hand Fallacies is apparent from the graph as well. Data falling below the ART represents the Gambler Fallacy, as this bias implies that events "cancel out." How does one cancel out the perception of a tornado? One assumes that the tornado is not going to happen, and if the tornado is not going to happen then participants are going to protect their airports at lower rates. For these reasons, data corresponding to the Gambler Fallacy falls below the ART.

On the other hand, data falling above the ART (as shown in String 7) represents the Hot Hand Fallacy. Here, individuals believe that tornadoes are going to happen uninterruptedly; therefore, one feels the need to continuously protect their airport. This corresponds to higher values along the y-axis and data falling above the ART.

3.2 Tendency for protective action: Probabilistic and deterministic forecasts

Airport protective response rates were also analyzed for individuals receiving probabilistic and deterministic graphic types as seen in Figure 4. Just as before, the mean (or ART) is represented via the red dashed line. Strings 3-6 as well as 8-10 show evidence of the Gambler Fallacy as the data generally falls below the ART. String 7 represents an interesting anomaly. Here, data falls above the ART as indicative of the Hot Hand Fallacy; however, after this pattern of 7 consecutive tornado events, the data takes a significant crash into String 8. Reasons for this crash are only speculative, but one theory is that participants felt a sense of overprotection in the smaller strings. After the seventh tornado, individuals chose to protect their airports less frequently—thereby, ensuing more risk—under the belief of the unlikely nature of the tornado's occurrence.

3.3 Tendency for protective action: Genders

When comparing airport protective response rates among males and females (Figure 5), similar patterns emerge as seen in Figure 4. The proportion of individuals taking protective action in males and females hovered below the ART in tornado Strings 3 to 6—thereby, indicating the Gambler fallacy. The rise in proportions—and subsequent crash at Sting 8—is also seen when comparing data across genders. However, dissimilar to Figure 4, Strings 8 through 10 (in Figure 5) displayed mixed results among variables parametrized. In large Strings 8 to 10, women displayed a higher protective tendency than men. Such finding holds consistent across psychology and cognitive science literature, as studies consistently conclude that women tend to be risk adverse while men are risk seeking.

4. DISCUSSION AND CONCLUSION

This paper analyzed public perception of weather risk via experimental tornado situations. In this regard, specific cognitive biases and heuristics were considered including the Gambler and Hot Hand Fallacies. This research demonstrated that perception of tornado risk becomes more convoluted as exposure to events increases—particularly, after patterns of 7 consecutive tornado events.

Further, such research demonstrates the connection between meteorology and social science. Results from this paper suggest that various groups within society perceive weather risk differently. This implies that unique messaging and education needs are beneficial in communicating weather risk to society. Specific recommendations with regards to best practices in messaging provide ground for further research. Regardless, exploration concerning the integration of social science within meteorology is critical in the twenty-first century weather enterprise. Such findings directly influence actions taken by individuals responsible for ensuring safety under severe weather. Therefore, there is tremendous societal benefit to studying and understanding public perception of weather risk.

Decision making is vital for human existence; yet, the processes by which our brains go about formulating judgements are mysterious and complicated. This is especially evident upon comparing protective response rates with regards to forecast type (deterministic and probabilistic) and gender. It is important to study public perception of weather risk due to large impacts on societal wellbeing. Therefore, it is ultimately through such research that findings concerning cognitive biases and heuristic in tornado warning response are illuminated.

APPENDIX 1

Figure 1: Deterministic forecast depicting a typical graphic given to participants in Klockow et al. (2013)'s study. The dot represents the fictitious airport's location.

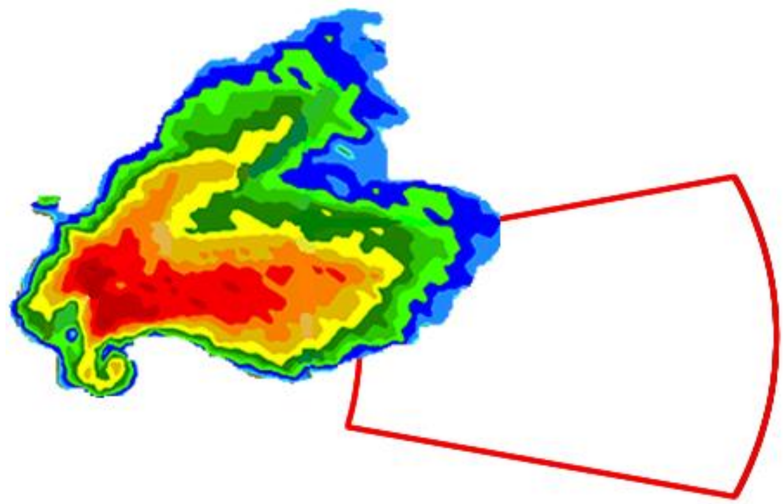

Figure 2: Probabilistic forecast depicting a typical graphic given to participants in Klockow et al. (2013)'s study. The dot represents the fictitious airport's location.

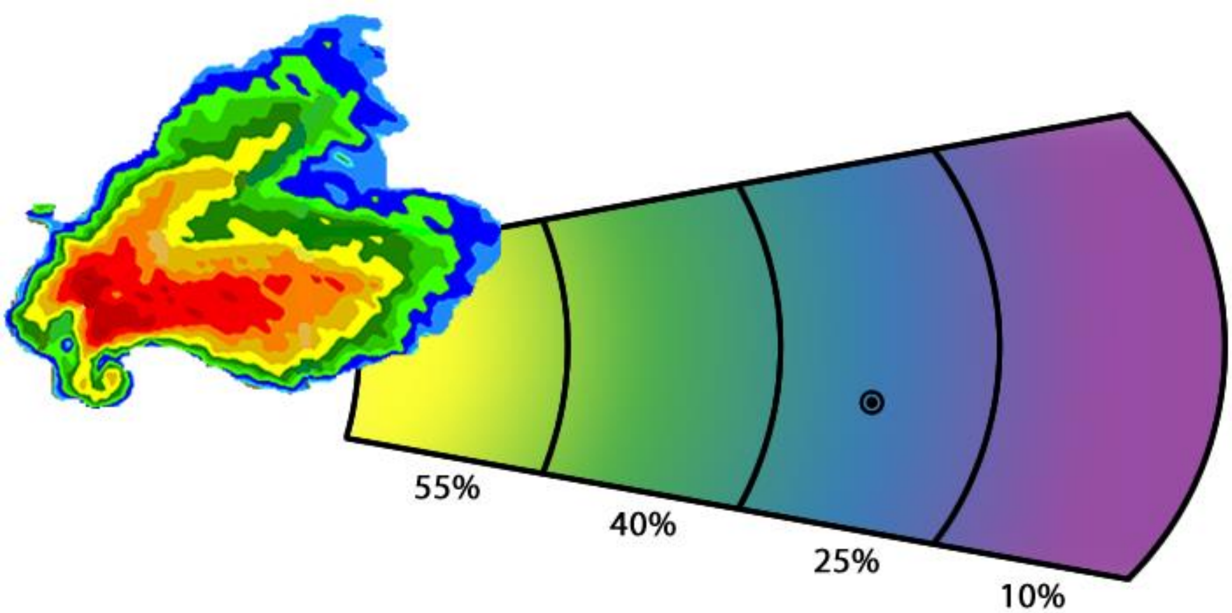

Figure 3: Displays the likelihood of an individual selecting the “Protect” option on their computer interfaces after a pattern (String) of tornadoes.

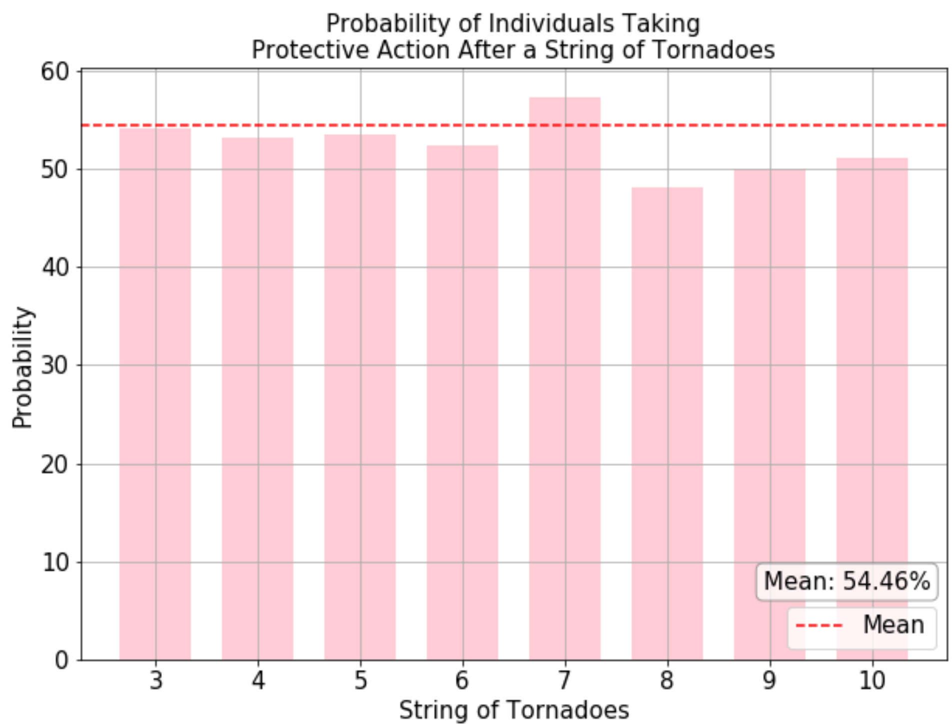

Figure 4: Displays how protective response rate varied for individuals given probabilistic and deterministic forecasts.

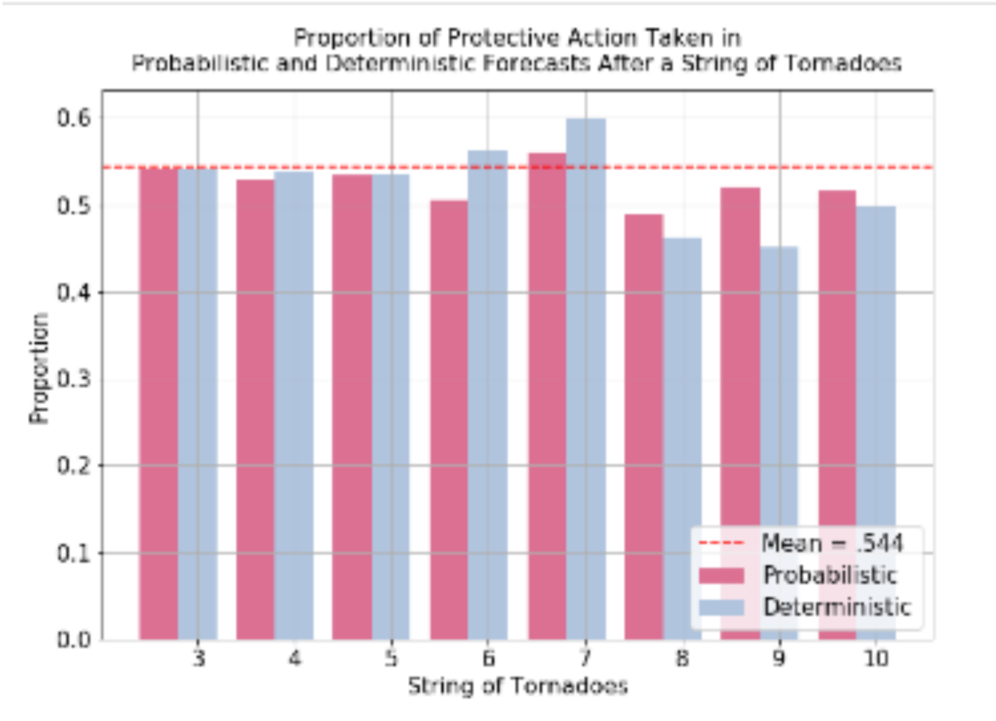

Figure 5: Displays how protective response rate varied for males and females.

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