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Dynamic Simulation as an Approach to Understanding Hurricane Risk Response: Insights from the *Stormview* Lab

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This article investigates the use of dynamic laboratory simulations as a tool for studying decisions to prepare for hurricane threats. A prototype web-based simulation named *Stormview* is described that allows individuals to experience the approach of a hurricane in a computer-based environment. In *Stormview* participants can gather storm information through various media, hear the opinions of neighbors, and indicate intentions to take protective action. We illustrate how the ability to exert experimental control over the information viewed by participants can be used to provide insights into decision making that would be difficult to gain from field studies, such as how preparedness decisions are affected by the nature of news coverage of prior storms, how a storm's movement is depicted in graphics, and the content of word-of-mouth communications. Data from an initial application involving a sample of Florida residents reveal a number of unexpected findings about hurricane risk response. Participants who viewed forecast graphics, which contained track lines depicting the most likely path of the storm, for example, had higher levels of preparation than those who saw graphics that showed only uncertainty cones—even among those living far from the predicted center path. Similarly, the participants who were most likely to express worry about an approaching storm and fastest to undertake preparatory action were those who, ironically, had never experienced one. Finally, external validity is evidenced by a close rank-order correspondence between patterns of information use revealed in the lab and that found in previous cross-sectional field studies.

KEY WORDS: Adaptation; decision making; hurricanes; laboratory simulation; natural hazards

1. INTRODUCTION

Recent worldwide losses of lives and property from natural hazards have underscored the need to develop a better understanding of how residents process forecast and warning information when making protective-action decisions.(1–3) Although there exists a large literature describing the correlates of risk perception and long-term preparedness in contexts such as earthquakes and hurricanes,(3–7) we know much less about the dynamics of information processing and protective choices when hazards are imminent, such as when hurricanes are approaching a coast or when flood or tornado watches have been issued for a location. The reason, at least in part, is

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pragmatic: as these are rare events, researchers have few opportunities to empirically study how residents prepare for hazards as they are actually unfolding, or test hypotheses about how forecast and warning information might be better conveyed.[1,8]

The purpose of this article is to remedy this deficit by reporting the findings of a program of research designed to gain such knowledge using dynamic web-based simulations in which residents experience hazards—in this case hurricanes—*virtually*. We describe the results of an application of a prototype hurricane simulation named *Stormview* that recreates the rich information environment that commonly characterizes the approach of hurricanes. As in an actual event, *Stormview* allows participants to watch television, listen to weather broadcasts, surf the web, and even hear the opinions of neighbors as a storm approaches. We show how *Stormview* can be used to gain new insights into the processes of decision making that are difficult to gather in the field, such as how information seeking evolves over time in response to growing threats, and how preparation decisions might be affected by changes in the type of forecast graphics viewed by residents.

We organize our presentation in four sections. In the balance of this section we motivate our work by reviewing prior work on two topics: local residents' patterns of gathering and interpreting information when making decisions to prepare for storm events, and the factors that have been hypothesized to affect preparation levels. In Section 2 we describe the origin and structure of the *Stormview* simulation, and relate it to other potential simulation-based approaches to studying decision making. In Section 3 we report the primary research findings, and in Section 4 we discuss the implications of the work for hurricane warning communication and for research approaches for studying natural hazards.

1.1. The Dynamics of Hurricane Risk Response

When a tropical cyclone threatens, coastal residents often face no shortage of information about the approaching storm. In the United States, weather websites hosted by the National Hurricane Center (NHC), Weather Underground, and the Weather Channel disseminate a wide range of graphical and text products derived from materials that are prepared by NOAA's Tropical Prediction Center. This information includes storm forecast tracks generated by different computer models, textual forecast discussions, and probabilistic wind field and storm surge maps. Television and radio stations transmit storm reports in a variety of formats. Social influences—be they conveyed by word of mouth or through social media sites—may also serve as a major source of both information and influence as storms approach.

Although empirical evidence on the dynamics of how information is gathered and processed during the course of a hurricane threat is limited, prior research on response to warnings in other contexts suggests that the process is likely to involve successive stages of information gathering, search, threat appraisal, and protective response.[2,9,10] To illustrate, when a resident first becomes aware of a storm threat, he or she may seek information about its severity from such sources as authorities, the news media, and peers.[11] This initial threat appraisal, in turn, will determine the level of protective response the resident feels is appropriate. The exact sources of information sources of information that are turned to and protection actions that are taken will, of course, vary from individual to individual. New residents facing storm threats for the first time, for example, might show a greater tendency to seek information and advice from friends and neighbors than their more experienced counterparts, and residents who have suffered property losses from past storms might be quicker to take protective action given knowledge of a storm threat.

Although there is a reasonably large literature describing some of the sociodemographic correlates of hurricane risk perceptions and information utilization,[12–19] almost all of it draws on field surveys conducted days or weeks after storm events.[20–23] Because residents' memories are likely to be imperfect, we currently know far less than we would like to about the dynamics of how information search patterns change over time during the course of storm threats, the kinds of information that serve to trigger decisions to take protective action, and how these dynamics vary across individuals. Perhaps most critically, we also have little basis for answering important counterfactual questions about how levels of preparedness might be *different* if alternative kinds of information were provided to residents.

In this article, we describe how such knowledge might potentially be gained from information search and decision-making behaviors revealed by residents while responding to *simulated* hurricanes. In particular, we describe the findings of an initial application of a prototype system, *Stormview*, which attempts to recreate in a computer-based setting many of the features of the information environment that would accompany a real-world storm threat. In addition to providing data about how patterns of information gathering and usage during the course of a storm threat varies among individuals and over time, the simulation allows researchers to conduct experimentally controlled tests of hypotheses about how changes in the information environment might affect information utilization and preparedness. In particular, in this work we use *Storm-view* to investigate three major long-standing questions about drivers of hurricane response:

(1) *The severity of prior storms:* To what degree does the frequency and severity of the hurricanes that precede a storm in a given season affect levels of concern and resulting preparedness?
(2) *The portrayal of uncertainty in forecast graphics:* There is suggestive evidence that individuals misinterpret track forecasts conveyed through the "cone of uncertainty" by paying too much attention to uncertain center track lines.[20,21] How might preparedness decisions differ were such "center track" forecasts never provided to the public?
(3) *Social influences:* How important are social influences in individuals' decisions to prepare for hurricane events, and how does the valence of attitudes toward storm threats expressed by others affect these decisions?

We emerge with three major sets of findings that have both methodological and applied implications. First, although the hurricane experienced by participants was only hypothetical, response behaviors parallel those that one might expect to see in advance of a real storm; information search patterns, for example, mirror those uncovered in past post-storm surveys about information use during hurricanes, by displaying a heavy emphasis on television as a focal source.[20,21] Second, the simulations provide a number of expected findings about the factors that drive storm risk perceptions and preparedness. We find, for example, that showing participants forecast graphics containing track lines that depict the most likely path of the eye of the storm increases both concern and levels of preparation relative to cases where participants are shown only uncertainty cones. This finding holds even among those who live far from the predicted center path. Similarly, the participants who express the highest degrees of worry about the approaching storm and are fastest to undertake preparatory action are those who, perhaps counterintuitively, have never experienced a hurricane in the real world. Finally, we find evidence that individual patterns of information gathering can be grouped into a small number of source strategies, which are systematically predictable based on background characteristics of decisionmakers.

2. THE *STORMVIEW* METHODOLOGY

Stormview owes its origins to a general methodology for studying of information gathering and choice in realistic computer-mediated environments termed information acceleration (IA). First developed by Glen Urban and colleagues at MIT in the 1990s, IA was conceived as a method for forecasting consumer demand for products that will appear on the market only in the distant future, such as concept cars.[24,25] The goal of IA is to use computer simulations to "accelerate" the lengthy process that would normally characterize how individuals learn about complex innovations. In a typical application, participants are first shown fictional news articles set at a date in the future when the innovation is likely to be available on the market. They are then shown an information dashboard that allows them to learn about the product through a variety of natural sources, such as television ads, news articles, and hypothetical friends and neighbors (portrayed by actors). The exercise concludes with participants being given an opportunity to make a virtual purchase of the product.

In *Stormview*, we extend this methodology to the case of a multiperiod storm event in which participants virtually experience the approach of a hurricane much as they would in the real world. A public demonstration version of the simulation is available on the web at https://cessna.wharton.upenn.edu/stormview/index.php?id=marketing (username: storm; password: storm). The simulation is built around five sequential modules:

(1) *Basic instructions and time orientation*. Participants first read a set of basic instructions about the simulation as well as the assumptions they should make about its geographic and temporal setting. In the application to be described participants (all Florida residents) were instructed to imagine that it was two years in the future, and they would be living in their same homes and have the same jobs and family situations that they have now.
(2) *Storm-season acceleration and framing*. Participants are then asked to read a series of fictional news articles about the storms (and/or other related events) that have preceded the simulated hurricane that season. The goal of

Fig. 1. The virtual living room in *Stormview*.

this phase was both to prime participants to think about tropical storms much as they would were it a real hurricane season, and to provide researchers with an opportunity to have experimental control over the intensity of this priming.

(3) *Information search: the virtual living room.* After completing the initial orientation, participants begin the central phase of the task in which they are given the opportunity to gather information about a developing tropical storm. This information is gathered by navigating a "virtual living room," depicted in Fig. 1. Participants can gather information by clicking any of four icons at the bottom of the screen corresponding to different media channels. Four major media channels were made available: television, radio, the web, and word of mouth (neighbors). If "the web" is selected (depicted by a notebook computer icon), a new window would open up that allows participants to visit hypothetical websites from a newspaper, a weather blog site, or the NHC. If the NHC site was selected, participants could further drill down to view forecast maps for the storm, computer model forecasts, satellite photos, public text advisories, or forecast discussions. If "neighbors" was selected, a new window opened where participants could view video clips of four different hypothetical neighbors talking about the storm.

(4) *Decision module*. After gathering as much information about the storm as desired, participants exit the living room by clicking the clock icon on the screen shown in Fig. 2, at which time they are taken to a short survey page that asks a series of questions about their beliefs about the storm threat and their likely preparation actions. The complete set of questions asked of respondents after each time phase is reproduced in Appendix A.

(5) *Time advance and simulation iteration.* After completing the decision survey, participants then view a screen that informs them that time has advanced to a new date and hour, and they return to the living room for a new round of information gathering.

2.1. Application to the Study of Information Gathering and Preparedness Decisions by Florida Residents

2.1.1. Overview

To explore the feasibility of studying hurricane response behavior in a web-based setting we used *Stormview* to simulate the development and approach of a future hypothetical hurricane named "Gabrielle" that posed a threat to southern Florida. The simulation involved four sequential chapters that portrayed the initial development of Gabrielle as a tropical storm in the Atlantic Ocean east of the Leeward Islands (chapter 1), its intensification to a hurricane as it approached the Virgin Islands (chapter 2), its intensification to a major category 4 storm just east of the southern Bahamas along with the issuance of a hurricane watch (chapter 3), and

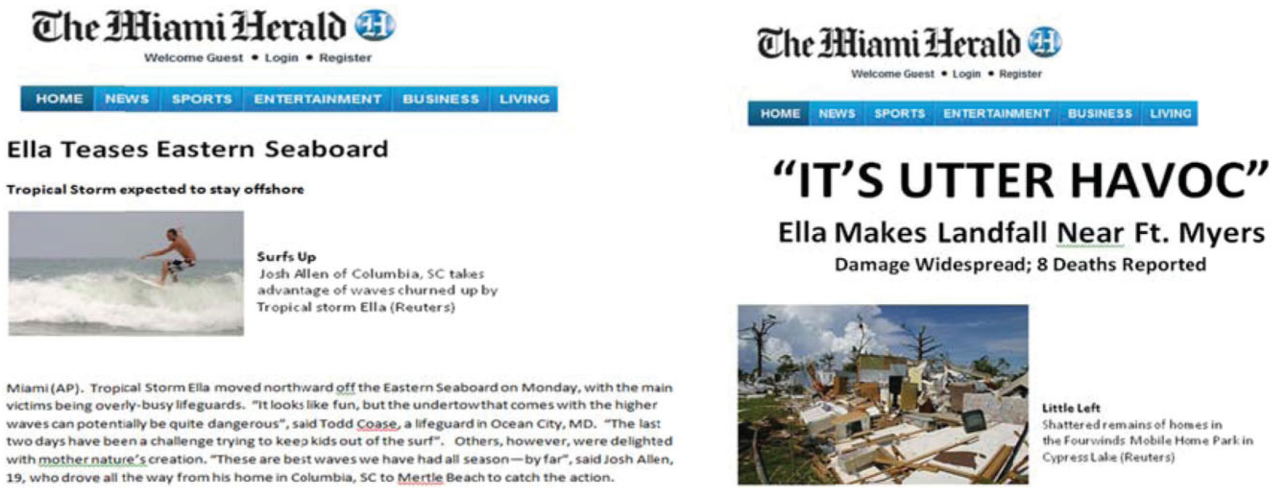

Fig. 2. Examples of news articles depicting hypothetical hurricane activity before Gabrielle in the calm season condition (left) and active season (right).

the issuance of hurricane warnings for the southern Florida peninsula as it approached the central Bahamas (chapter 4). After completing the final chapter, participants were taken to a concluding screen in which it was revealed that Gabrielle made landfall on the east-central coast of Florida as a weaker-than-expected category 2 storm and did moderate damage. They were then asked to complete an exit survey that included a series of sociodemographic questions (e.g., age, gender, income, education, location, housing type) as well as questions related to their previous experience with hurricanes (whether they had experienced one and whether they had suffered damage).

To mimic the uncertainty that would normally accompany a hurricane, at the start of the simulation participants were given no information about the likely future movement or intensity of the storm, nor were they told how many time stages of the simulation they would experience. Participants were told only that they would have the opportunity to gather information about a future hypothetical storm that may or may not threaten land, and that the overall simulation would last approximately 30 minutes. In addition, instructions emphasized that they should attempt to make all decisions in the same manner that they would were the storm a real one.

2.1.2. Experimental Design

Upon logging into the system, participants were randomly assigned to one of eight different versions of the simulation. These versions corresponded to a 2^3 factorial design that varied between participants:

(1) The level of storm activity within the season before Gabrielle (active or quiet);
(2) How forecast maps depict the storm's future movement (whether the cone did or did not contain a center track line); and
(3) The degree of concern about the storm expressed by neighbors (worried or not worried).

Participants then viewed four chapters of the storm threat within each of these conditions. The design was thus a mixed between-within full factorial, with three between-subjects factors (prior activity, line/no line, neighbor concern) and one with within (simulation chapter).

"Active" or "quiet" season was manipulated by varying the content of nine hypothetical newspaper articles that participants read about the storms preceding Gabrielle at the start of the simulation. In particular, in the "quiet season" condition, participants first read an article indicating that forecasters expected the simulation hurricane season to be a quiet one because of *El Niño* conditions, and this was followed by a series of congruent articles describing each storm as minor events that either caused little damage or never affected land. In contrast, in the "active season" condition participants read articles depicting the opposite; the first article indicated that forecasters believed it would be an active season (because of *La Niña* conditions), and subsequent

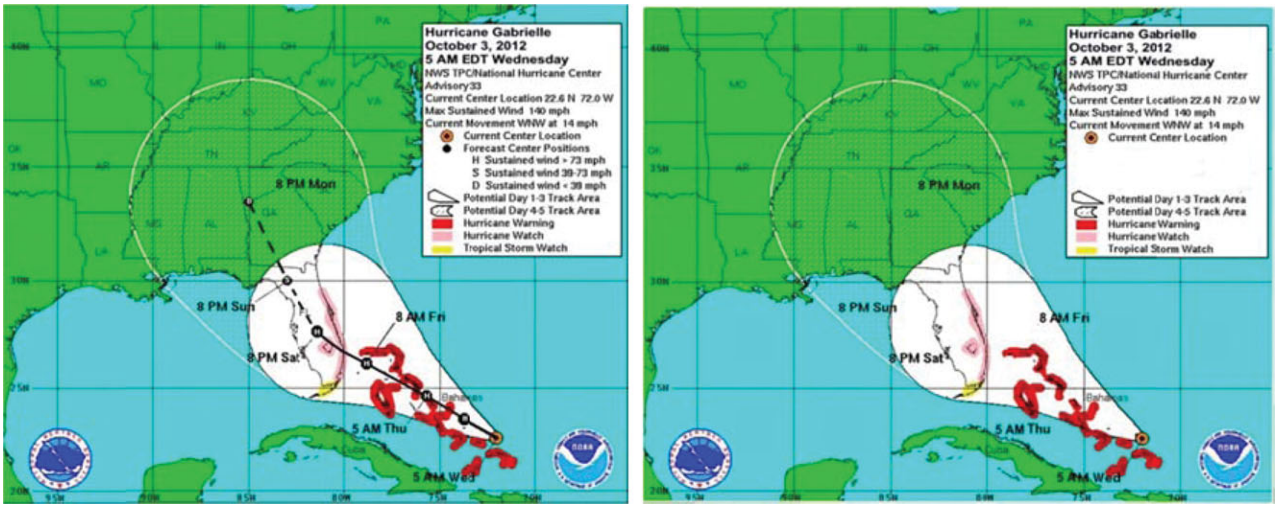

Fig. 3. Forecast map manipulation: with center track line (left) or without (right). Maps are as they appeared in chapter 3 of the simulation.

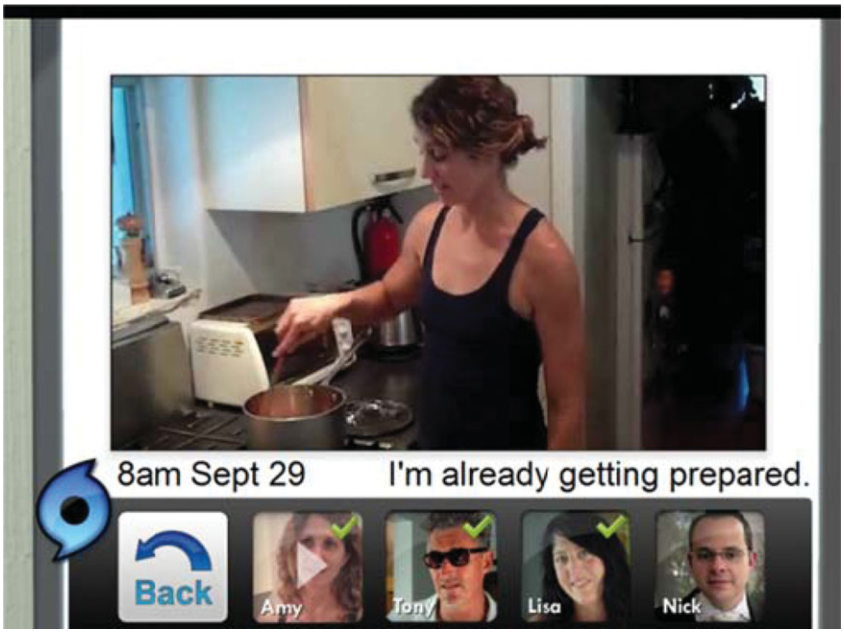

Fig. 4. Illustrative screen shot of neighbor video clip in the worried condition.

articles describing a series of severe storms that caused major damage in the United States. Examples of articles from the two conditions are reproduced in Fig. 2.

The different forecast maps were manipulated as well; participants who visited the NHC website were shown one of two map styles as depicted in Fig. 3.

The maps were designed to typify the map styles of those currently used by NOAA's Tropical Prediction Center to display the current storm forecast.

Finally, the degree of concern expressed by neighbors was manipulated by having three of the four video clips of neighbors speaking about the storm to convey either high levels of worry or relative indifference about the storm threat.[5] As shown in Fig. 4, the central message conveyed in the clip (either worry or indifference) was reinforced by a text summary beneath the main video screen.

[5]To illustrate, in the high worry condition three video clips would depict actors expressing high levels of concern about the approaching storm, with the fourth expressing comparative indifference.

Although the prestorm information, forecast graphics, and neighbors' risk attitudes viewed by participants varied across experimental conditions, all other sources of information content were the same for all participants. Hence, for example, all participants viewed and/or listened to the same simulated television and radio weather broadcasts, and viewed the same simulated text advisories and satellite photos provided by the NHC.

2.1.3. *Participants*

Participants were 356 residents of southern and central Florida who were members of a survey panel maintained by Knowledge Networks. Because each respondent was randomly assigned to one of eight cells of a 2^3 factorial design, this sample yielded between 43 and 46 participants per experimental cell, with each participant making four sets of judgments within each cell, corresponding to the four chapters of the simulation. The sample represented a reasonably broad cross-section of Florida homeowners: 59% were female with a median age of 46–60 years (ranging from 10% under 30 years to 1% over 80 years), 55% had a college degree, 66% lived in single-family homes, 79% owned (as opposed to rented) their residences, and 90% had experienced a hurricane (the general area had been hit by five storms of hurricane strength between 2004 and 2005). All simulations were completed over a one-month period between February and March 2011. Of the original pool of respondents, 35 were deleted because of incomplete records, and 11 more were deleted before analysis for revealing response times that suggested overly cursory participation in the simulation, as defined by spending less than 45 seconds reading the eight initial news articles and/or spending less than 15 seconds gathering information within each chapter.

3. ANALYSIS AND RESULTS

3.1. Overview

The *Stormview* simulation provides a rich array of information about how respondents learned about the storm and responded to gathered information. Each mouse-click action taken by the respondent is automatically recorded with a unique time stamp, and these data allow us to recover the order and duration of all information gathering activities. In addition, as noted above, at the conclusion of each time chapter, an array of measures are gathered describing the participant's risk attitudes and likely preparedness responses in light of gathered information (Appendix A).

We report the findings of the study in three phases. We begin with an overview of how participants responded to the increasing threat posed by Gabrielle as measured by risk attitudes and decisions to take preparatory action, and the findings of a structural model of individual preparedness decisions. We then explore in detail the process by which individuals gathered storm information from different sources in the task. We conclude by reporting the results of experimental tests of how variations in prestorm hurricane activity, neighbors' risk attitudes, and the format of storm forecast graphics affected appraisals of risk and preparation levels.

3.2. The Evolution of Risk Attitudes and Preparation Decisions

To provide an overview of how participants responded to the virtual hurricane threat reproduced in the simulation, in Fig. 5 we plot the evolution of two summary measures of storm response: mean worry about the storm, and the likelihood that the participant's home would experience hurricane-force winds (measured on seven-point scales; see Appendix A for exact wording).

The figure suggests that participants responded to the increasing threat posed by Gabrielle in a manner paralleling that which one might expect to observe in an actual storm event: mean worry and hurricane-wind likelihoods closely track one another, increasing from approximately 3.5 when the storm was in its formative stages east of the Leeward Islands in chapter 1, to over 6 ("extremely worried," "extremely likely") when hurricane warnings were issued in chapter 4.

To explore how these increasing levels of concern translated into preparation actions, in Fig. 6 we plot the relative frequency with which participants indicated an intention to undertake each of eight different preparation actions over time. When Gabrielle was a distant threat in chapter 1 and before any warnings were issued, less than a third of participants revealed an intention to undertake preparedness actions, and those activities that were undertaken required minimal effort, such as buying supplies. When a hurricane watch is issued in chapter 3, however, there was a large increase in the proportion of participants reporting an intent to take some

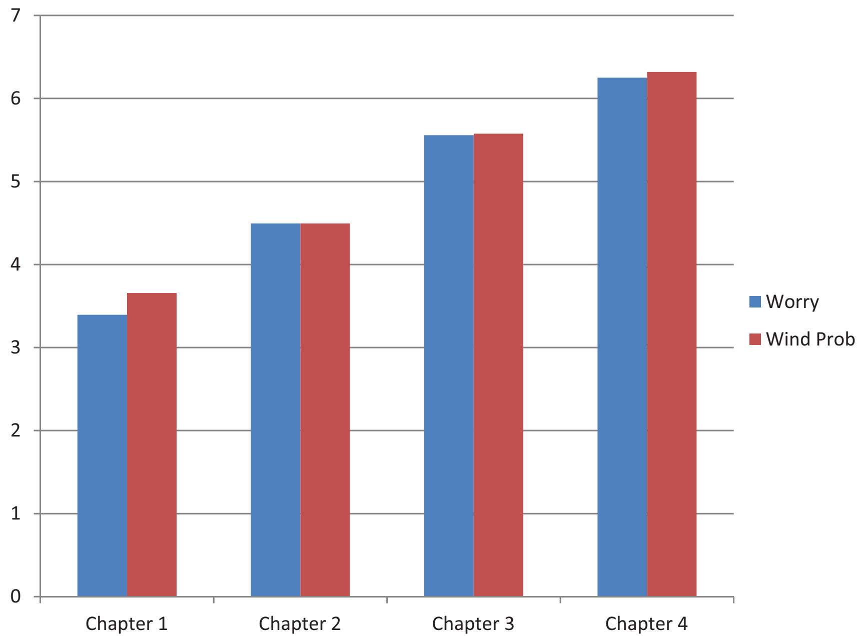

Fig. 5. Mean rated worry and subjective odds of experiencing hurricane-force winds by simulation chapter (each measured on seven-point scales).

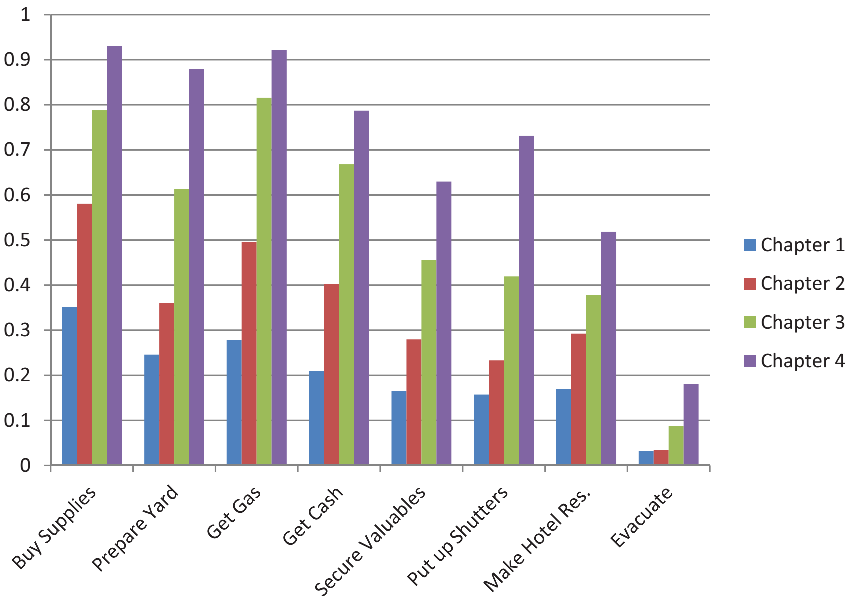

Fig. 6. Cumulative relative frequencies of preparation actions by chapter.

form of preparedness action. Intentions to undertake the most effortful actions—putting up shutters and deciding to evacuate—generally did not emerge until the issuance of actual warnings in chapter 4. Hence, though observed in a simulation, participants' behavior paralleled intuitive notions about how storm preparation would proceed over time in advance of a storm, with the most effort-intensive actions commencing only when participants perceived the storm risk had reached high levels.

To investigate in greater detail what drove decisions to take protective action, we estimated a series of structural models of how information gathered from different sources and subsequent concern affected decisions to undertake different kinds of preparatory actions, averaging over the experimental manipulations (the effects of which will be discussed later). The general model structure, portrayed in Fig. 7, followed previous proposals for how individuals decide to take protective action[2,10] by

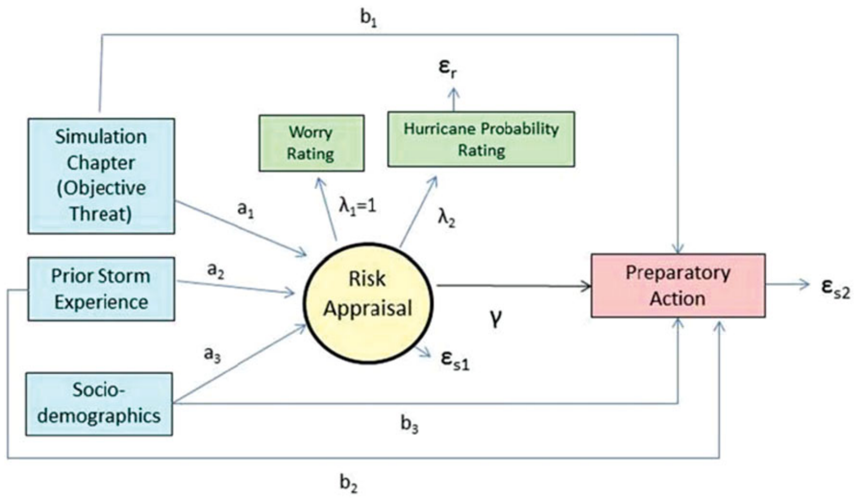

Fig. 7. Estimated structural model of preparation decisions.

assuming that upon gathering information about the storm in each given chapter, the participant would first form an appraisal of the risk posed by the storm. Concern was modeled as a function of the objective threat communicated by the information (manifested by chapter indicator variables), the participant's prior experience with hurricanes, and personal background characteristics. The decision whether to undertake preparatory action was then modeled as a direct function of concern about the storm and additional direct functions of objective risk and background characteristics, including past storm experience. We estimated this structure for six different preparation measures: the cumulative number of preparatory actions that a participant had taken by the end of a given chapter, and whether the participant had undertaken one of five illustrative preparatory actions: "buy supplies," "fill car with gas," "put up shutters," "make a hotel reservation," or "evacuate."

Maximum-likelihood estimates of the parameters of the risk appraisal and preparatory action models are reported Table I, and the raw bivariate correlation matrix of the dependent and independent variables is reproduced in Appendix B.[6] Supporting the hypothesized decision process, the primary drivers of decisions to take preparatory action were (1) the mean objective size of the threat communicated by the various media sources in each chapter as captured by the chapter indicator variables; and (2) the participant's personal appraisal of its severity (latent concern). In addition, after controlling for levels of concern, for most protective actions the likelihood of undertaking the protective action was conditioned by current homeownership; those owning their homes undertook a larger number of actions, were more likely to install shutters, secure hotel reservations, and, ultimately, evacuate.

Consistent with prior work that has examined gender effects on risk taking,[(26)] the data also show that decisions to undertake protective action were affected by gender; however, this effect was somewhat more complex than that of homeownership. On the one hand, we see no direct effect of gender on overall levels of expressed concern about the threat posed by Gabrielle—a result that might be seen as conflicting with research on gender effects on risk attitudes. On the other hand, we *do* see a direct effect of gender on preparatory action; for the same level of concern, female participants were more likely to indicate a desire to take protective action as measured by the number of actions: filling their cars with gas, securing hotel reservations, and evacuating.[7]

Perhaps the most intriguing driver of both worry and decisions to undertake protection that we observed, however, was that of prior storm experience. As noted by Lindell *et al.*,[(16)] prior research that has attempted to measure the effect of prior storm experience on risk perception and decisions to take protective action has been inconclusive in its findings. For example, whereas Trumbo *et al.*[(3)] found that residents with prior hurricane experience were more likely to believe that their home is at risk for future

[6]Parameters were estimated using the SAS procedure Proc Calis.

[7]In additional analyses not reported here, there was a similar significant direct gender effect on obtaining extra cash, but not on securing valuables or taking in lawn furniture.

Table I. Maximum-Likelihood Estimates of Structural Models of Preparation Actions

	Model							
Variable	Concern	Concern	# Preps	Buy Supplies	Get Gas	Shutters	Hotel	Evacuation
Worry	1							
Wind Prob	0.87**							
Concern (latent)			0.59**	0.46**	0.43**	0.39**	0.37**	0.25**
Chapter 2		0.28**	0.03	0.10**	0.08**	−0.04	0.00	−0.07*
Chapter 3		0.57**	0.18**	0.15**	0.21**	0.05	−0.01	−0.08*
Chapter 4		0.75**	0.18**	0.18**	0.21**	0.20**	0.04	0.03
Experience–no damage		−0.18**	−0.06*	−0.09*	−0.02	−0.09	−0.07	−0.07
Experience–damage		−0.08*	−0.01	−0.09*	0.04	−0.05	−0.10*	−0.10*
Age		0.01	−0.01	−0.02	0.02	−0.06*	0.00	−0.06*
Female?		0.02	0.06**	0.02	0.10**	−0.01	0.06*	0.07**
Own?		0.04*	0.10**	0.03	0.04	0.06*	0.21**	0.14**
Income		0.04	−0.01	−0.05*	0.02	0.00	0.05	0.03
Education		0.01	0.00	0.01	0.02*	0.03	−0.05*	−0.04
Household size		0.02	0.07**	0.03	0.03	0.08**	0.00	0.08**
SEM model fits								
Chi square			89.61	75.16	66.76	65.56	62.92	64.89
AIC			67.61	51.16	42.76	41.56	38.92	40.89
$N = 1186$								

$^{*}p < 0.05$; $^{**}p < 0.01$.

hurricanes, Baker[(12)] suggests that prior experience is less of a consistent predictor of *short-term* responses to threats, in particular, evacuation. The possible reason for this equivocation is the ambiguous signal that storm experiences can provide. Although one might conjecture that those in our sample who had lived through hurricanes and witnessed first-hand the damage they can cause may be more inclined to indicate intentions to undertake preparedness, it is worth noting that the hurricanes that affected the south and east Florida study areas over the last decade (primarily the 2004–2005 hurricane seasons) were not particularly intense ones. As such, for many, their experiences may have taught them that hurricanes are, more often than not, merely inconveniences as opposed to life-threatening events. To investigate this issue, our structural models of concern and preparation included two dummy variables that captured the two possible kinds of storm experience (to contrast with those who had never lived through a storm): whether a respondent had experienced a hurricane but did not suffer damage, or experienced a hurricane and did suffer damage.[8]

The results of the analysis show a systematic effect of both kinds of past storm experience, but of an unexpected nature: prior experience with a hurricane—regardless of whether it produced damage or not—significantly *decreased* expressed concern about the storm and, ultimately, intended preparation, as shown in Table I. This effect was reflected in significant negative effects of past experience on storm concern, as well as an additional direct negative effect of storm experience on total preparation (controlling for concern). Although the direct effect of experience in preparation was not observed for all specific actions, it was observed for those that were, arguably, most important for storm survival: buying supplies, securing hotel reservations in case evacuation was needed, and evacuation itself. In short, the data produce a response pattern that some might see as paradoxical: the participants who were most likely to take protective action in advance of Hurricane Gabrielle were those who had never faced such a storm in real life.

3.3. Information Utilization Patterns

To provide some initial insights into how participants utilized the various sources of information available to them in the simulation, we constructed

[8]As shown in Appendix B, the dummy variables "experience with damage" and "experience but no damage" as contrasts with "no experience" were, as one would expect, negatively correlated in the data (r = –0.61). Although this intercorrelation was sufficiently low to permit recovery of unbiased estimates, their separate partial effects, the exact tabled values, must be interpreted with caution because of the inflated standard errors of the estimates.

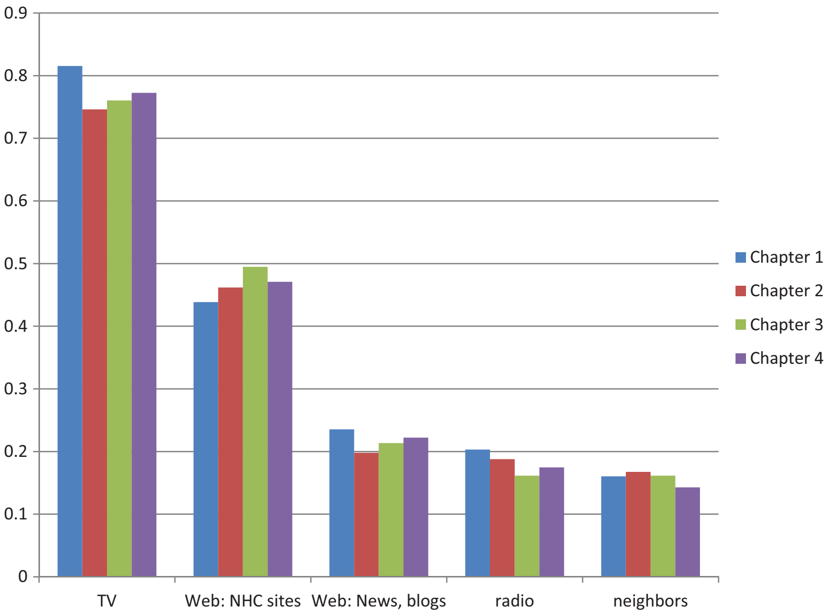

Fig. 8. Proportions of respondents who searched each of the five information channels, by chapter.

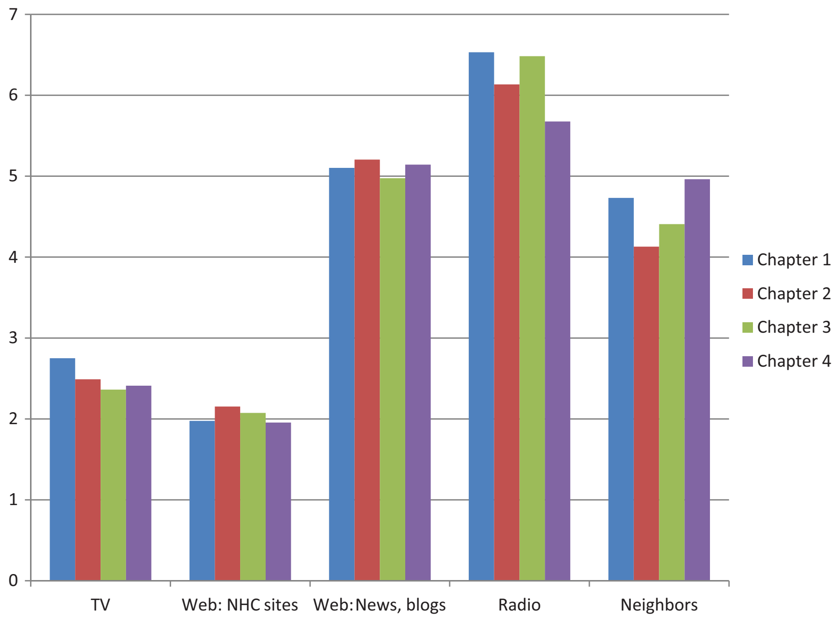

Fig. 9. Mean conditional rank order with which each of five major channels of information were searched by simulation chapter. Lower mean ranks imply a source was accessed earlier in the search process among examined sources.

two sets of information-use measures for each respondent:

(1) *Acquisition.* A dichotomous measure of whether or not a respondent acquired a given category of information category during the course of a given time chapter; and
(2) *Priority.* The rank-order sequence in which a category of information was first viewed. Priority rank was calculated over all acquisitions, so, for example, if a respondent searched among sources in the sequence (web, TV, web, radio), "radio" would have a priority rank of four.

In Figs. 8 and 9 we plot the means of these statistics for television, radio, and neighbors, plus two subcategories of information available from the simulated Internet: web news and blogs, and the storm information from the NHC. The figures yield three major findings. First, television and the NHC site emerged as the dominant channels through which participants acquired information about the storm: they were the most frequently utilized sources of information across participants (led by television; Fig. 8), and were accessed early in the search process (Fig. 9). Second, social sources (neighbor video clips) emerged as a surprisingly unimportant source of information about the storm; on average, the source was accessed by only 15% of subjects within each chapter (Fig. 8), and when it was accessed it was only after other sources (two on average) had been pursued (Fig. 9). Third, the data also show that this rank ordering of importance of information was largely constant across the four simulation chapters. The data show no evidence, for example, that participants artificially accessed a wider range of sources earlier in chapter 1 in response to the novelty of the task (this would seem particularly likely for the neighbor video clips), or that they reduced the scope of information gathering as the task waned.

To explore in greater detail the heterogeneity that existed in information utilization patterns, we subjected individual-level data on the sources of information accessed by each participant for each of the four time chapters to a latent cluster analysis using the model-based clustering algorithm *mclust* in *R*.[27] In this approach, the distribution of processing patterns was modeled as a normal mixture of several discrete segments or components. Bayesian information criteria were used to find the solution that provided the most parsimonious account of heterogeneity in the data.

The analysis suggested that information utilization could be parsimoniously described by four patterns (see Fig. 10):[9]

(1) A *web-centered* strategy in which individuals focused on information from web sources (15% of participants);
(2) A *television* strategy in which individuals looked at very few sources of information (1.28 on average), with the majority choosing to consult television (58% of participants);
(3) An *intensive search* strategy in which individuals gathered, on average, 8.74 sources of all types (12% of participants); and
(4) A *forecast map* strategy in which individuals focused on information provided by the map sources in the simulation: television, the NHC forecast map, and computer model forecast map (14% of participants).

Note that these clusters describe differences in the relative frequency with which different kinds of information were sought by participants, and do not attempt to capture more subtle differences that may have existed in the *sequence* with which information was gathered; for example, in the forecast map group, whether some tended to viewing the television map before going to the web, and some vice versa.

In Table II, we report the mean sociodemographic, storm experience, and storm-response characteristics of each of these information-strategy clusters. We also report the results of two one-way MANOVAs that tested the equivalence of the clusters over the reported batteries of background characteristics and storm responses, respectively. These analyses suggested that the strategy clusters were associated with a unique pattern of respondent characteristics and storm responses. The television-only cluster, for example, tended to include a greater proportion of women, was of somewhat lower income, reflected smaller households, and had greater nondamage hurricane experience. In contrast, the web-centered cluster tended to have higher incomes, was better educated, and reflected larger households. The intensive-search cluster tended to include a larger proportion of younger participants. The data also suggested a positive association between the breadth of information gathering and storm concern. Individuals associated with the intensive-search cluster, for example, expressed the greatest mean level of worry and undertook the greatest number of preparations, although those who focused only on television expressed the least worry and undertook the fewest preparations. Unfortunately, the data do not allow us to draw conclusive inferences about the primary direction of causation in this association; that is, whether higher latent levels of concern induced more extensive information gathering, whether more extensive information gathering produced higher levels of concern, or, perhaps most likely, a reciprocal blend of both.

[9] For each potential cluster solution, eight possible models were evaluated via the Bayesian information criterion (BIC). The BIC initially showed a significant increase with the number of clusters (k), which became more gradual for $k > 4$. In addition, increasing the number of clusters to five or six did not significantly alter the visual interpretation. Thus, in this exploratory analysis we use the four-cluster solution, which provided the most parsimonious account of heterogeneity in the data. For $k = 4$, the BIC was maximized by a model consisting of spherical components of equal volume.

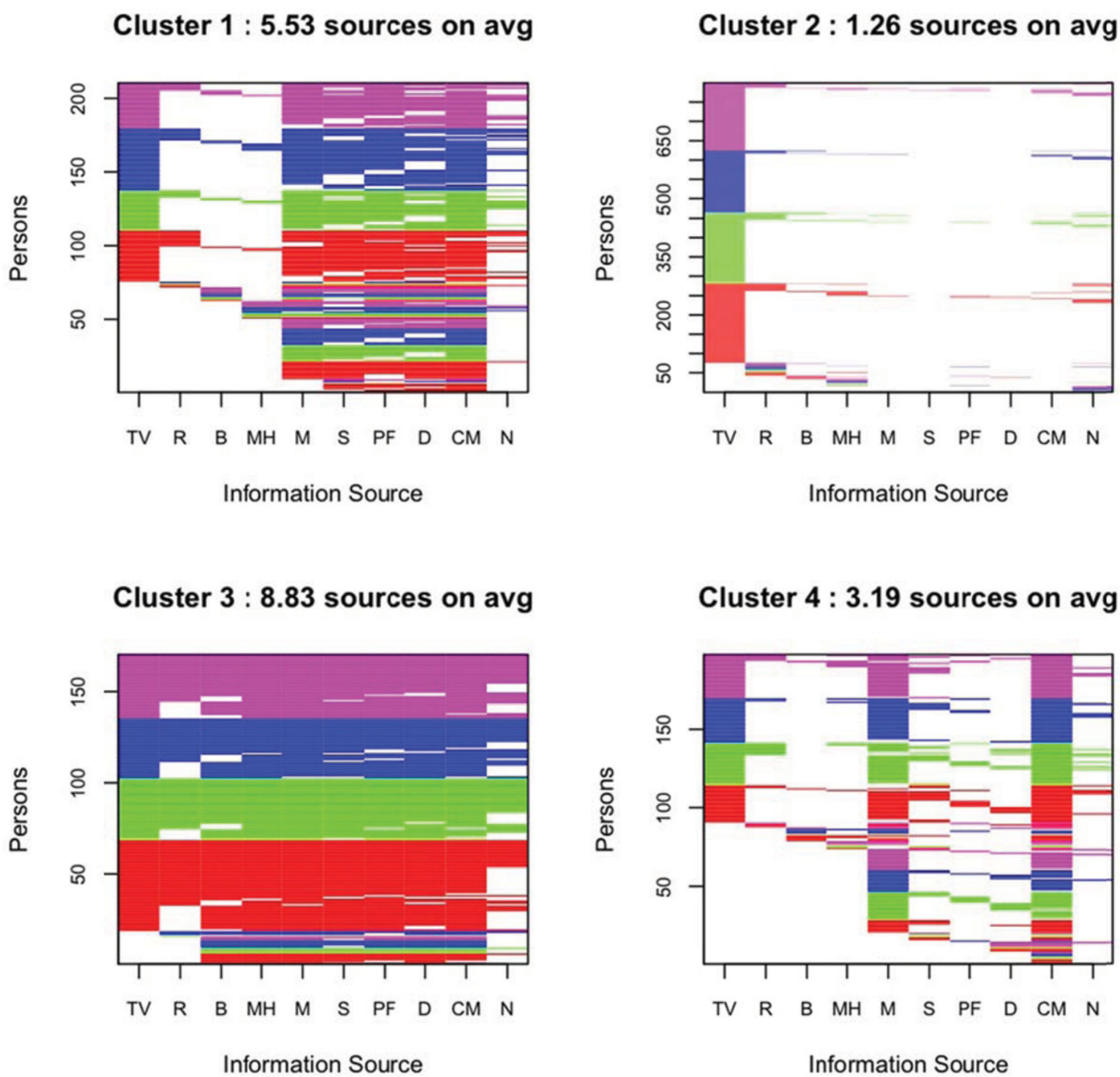

Fig. 10. Four-cluster solution of an analysis of heterogeneity of information search patterns across respondents. Each color band (color visible in online version) reflects information gathering frequencies in each successive chapter. Red = chapter 1. Key: TV = television; R = radio; B = blogs, MH = Miami Herald News; M = forecast map; S = satellite photos, PF = public forecast; D = forecast discussion; CM = computer models; N = neighbors. Dark lines reflect information sought by an individual in a given segment.

3.4. The Experimental Effects of Prior Storm Activity, Portrayal of Uncertainty, and Social Influence

One of the central advantages of lab simulations such as *Stormview* is the ability to answer counterfactual "what if?" questions that would be difficult to investigate in the context of a real storm. In this section, we illustrate this capability by describing the results of our experimental manipulations meant to address three major unanswered questions about hurricane response: the effect of variations in the nature of news coverage about hurricanes occurring during the same season leading up to a storm (priming), whether the forecast graphics viewed by residents include or did not include a centerline that depicts the current "center track" forecast of a hurricane, and levels of concern about the storm expressed by others (social influences).

3.4.1. The Effect of Prior Season Hurricane Activity

In the later stages of the active 2004 and 2005 hurricane seasons, suggestions were made that the high incidence of hurricane impacts in Florida and

Table II. (A) Mean Sociodemographics and Storm Responses by Information Gathering Cluster. (B) MANOVA Tests of No Overall Cluster Effects

(A) Mean Sociodemographics and Storm Responses by Information Gathering Cluster

	Web Centered	TV Only	Intensive	Map Focused
Age[e]	2.95[a,c]	3.26[b,d]	2.65[a]	3.03[b,c,d]
Female (1 = yes)?	0.49[a,b]	0.59[a]	0.60[a,b]	0.47[b]
Rent (1 = yes)?	0.19[a]	0.19[a]	0.36[b]	0.14[a]
Income (category)	13.25[a]	11.47[b]	11.11[b]	12.96[a]
Education (category)	3.45[a]	3.21[b]	2.92[c]	3.42[a]
Household size	2.74[a]	2.51[a]	3.31[b]	2.57[a]
Hurricane experience (1 = yes)	0.86[a]	0.78[a]	0.85[a]	0.87[a]
Mean worry	5.05[a,b]	4.75[a]	5.36[b]	4.73[a]
Number of preparations (of 9 possible)	4.43[a]	3.66[b]	5.76[c]	3.47[b]

(B) MANOVA Tests of No Overall Cluster Effects

	Sociodemographics and Experience Variables				Storm Response Variables			
	Value	F	DF	Pr > F	Value	F	DF	Pr > F
Wilks' lambda	0.92	4.92	21,3337	<0.0001	0.94	13.590	6,2662	<0.0001
Hotelling trace	0.09	5.00	21,3482	<0.0001	0.06	13.779	6,2660	<0.0001

[a,b,c,d] Not significantly different at $p < 0.01$.
[e] Categorical age groupings; $0 \leq 30$; 1: 30–39; 2 = 40–49; 3 = 50–59; 4 = 60–70; $5 \geq 70$.

the Gulf desensitized many residents to the threat posed by storms—a phenomenon labeled "hurricane fatigue."[28,29] Empirical evidence supporting the existence of fatigue, however, is largely anecdotal, and conflicts with the findings of more systematic research on the effect of repeated false alarms on hurricane evacuation rates, which has yet to find evidence of "cry wolf" or desensitization effects.[12,15] On the other hand, it is possible that desensitization may take more subtle forms, such as residents being less likely to engage in more common preparation activities (e.g., seeking supplies), or delaying the timing of evacuation.

By experimentally manipulating the content of the eight news articles that participants read at the start of the simulation, *Stormview* allowed us to gain some initial insights into whether active hurricane seasons might, indeed, desensitize individuals to new storms. As noted above, participants were randomly assigned to one of two preseason conditions: a "calm season" condition in which articles described a docile season where there had been no landfall impacts, or an "active season" where the articles recounted a series of major hurricane landfalls, with each storm causing major destruction, two in Florida (Fig. 2).

We analyzed the effect of the calm/active season manipulation by reestimating the structural models of concern and number of preparation activities reported in Table I including prior season activity as an additional covariate. The results of this analysis (not tabled), however, rejected the desensitization hypothesis. Specifically, the indicator variable reflecting whether participants were primed with either a calm or active season did not approach significance in either the models predicting storm concern or preparation. This lack of effect proved quite robust to more detailed modeling efforts (not reported here) that controlled for the length of time spent reading the articles, and the length of time spent reading articles that described the most damaging impacts in Florida (right panel in Fig. 2).

3.4.2. *Forecast Graphics*

A second major experimental manipulation that we explored using *Stormview* was the effect of viewing different forecast maps portraying the likely future movement of Gabrielle: an uncertainty cone that includes a center track line versus an uncertainty cone does not include a center track line (see Fig. 3). This manipulation was motivated by the findings of Broad *et al.*[30] that NHC graphics that included a center track line within an uncertainty cone depicting the likely future movement of the 2004 Hurricane Charlie were being misperceived by both residents and emergency managers, who tended to focus too much on the centerline. That study, however, did not address the critical counterfactual question of whether removing the center track line from forecast maps would help or hurt overall preparedness in threatened areas. Because removing the center track line would make the predicted landfall point of a hurricane more ambiguous, doing so might encourage a larger number of residents to believe that their community could be near the point of landfall (hence increasing overall preparedness), but it could just as easily increase the number who believe that their community will *not* be near the point of landfall (hence decreasing overall preparedness).

To investigate this question, we reestimated our structural models of storm concern and number of preparedness actions focusing just on those participants who viewed a forecast map at some point during the course of their information gathering (about 50% of respondents). Because the work by Broad *et al.*[30] suggested that the effect of map type may be conditioned by where a respondent lived with respect to the center track line, we included in the model covariates for map type (line or no line), a binary indicator of whether a respondent lived in the locations that would likely experience the most severe effects of Gabrielle based on the track line forecasts (Palm Beach or St. Lucie Counties; see Fig. 3), and the interaction of map type and location. Our hypothesis, based on the work of Broad *et al.*,[30] was that the effect of map type should be conditioned by location; with track lines amplifying the difference in expressed worry and preparation between those close to and away from the most likely landfall points.

The analysis, summarized in Table III, yields a straightforward—and possibly surprising—result: the presence of a center track line had strong *positive* direct effect on overall expressions of concern about the storm, though with no additional indirect effect on preparedness. In contrast, the analysis failed to support a main effect of respondent location or an interaction of location and map type. This latter result was sustained using both narrower and broader definitions of the likely impact point (Palm Beach County only or Broward, Palm Beach and St. Lucie Counties) as well as controls for the length of time each map type was viewed (not reported). Hence, compared to those who viewed the forecast cone without the track line, the data show that including the track line increased respondents' levels of concern about the threat posed by Gabrielle (hence, in turn, preparedness) for *all* participants regardless of whether their home was located in the targeted center of the cone or away from it.

Table III. Maximum-Likelihood Estimates of Structural Model of the Effect of Center Track Line and Location on Preparation

	Model		
Dependent Variable	Concern	Concern	# Preps
Worry	1.00		
Wind Prob	0.82**		
Concern (latent)			0.56**
Chapter 2		0.34**	0.03
Chapter 3		0.63**	0.13**
Chapter 4		0.02**	0.20**
Line (0,1)		0.19**	0.03
Location (0,1)		−0.04	0.02
Line*location		0.02	0.02
Experience–no damage		−0.13**	−0.04
Experience–damage		−0.16**	0.07
Age		0.05	−0.01
Gender (1 = female)		0.09*	0.09*
Rent/own (1 = own)		0.01	0.09*
Income		−0.01	0.04
Education		−0.02	−0.13**
Household size		0.02	0.04
Model fit			
Chi square			82.10
AIC			52.10
$N = 440$			

$^{**}p < 0.01$; $^{*}p < 0.05$.

What explains the global positive effect on concern of viewing maps with center track lines? Although the data are insufficient to provide a conclusive explanation, several hypotheses might be offered. One is that although maps with track lines may indeed focus residents' beliefs on where the center of a storm might go, the *absence* of a line may optimistically focus their beliefs on where it might *not* go—something that could assuage worry and diminish preparedness at the margin. Similarly, the presence of a track line may convey to residents a greater sense of certainty that the storm will, indeed, strike land, and they may (fortuitously) lack the meteorological knowledge to know that only locations near the point of landfall are likely to experience the maximum wind conditions described in NHC advisories. Finally, more generally, the mere lack of familiarity of maps that do not contain center lines might have also diminished participants' sense of concern when viewing them.[10]

[10] We might note, however, that maps without center track lines had become increasingly common at the time of the study, hence may not have been unfamiliar to participants; e.g., forecast maps shown on the Weather Channel only depict a cone, not a center track.

Table IV. Maximum-Likelihood Estimates of a Structural Model of the Effect of Expressed Neighbor Worry and Number of Neighbors Listened to on Preparation

	Model		
Dependent Variable	Concern	Concern	# Preps
Worry	1.00		
Wind prob	0.75**		
Concern (latent)			0.57**
Chapter 2		0.26**	0.07**
Chapter 3		0.56**	0.18**
Chapter 4		0.67**	0.19**
Calm neighbors		0.17	−0.26*
# Neighbors		0.36**	0.05
# x Calm		−0.46*	0.24
Experience–no damage		−0.33**	−0.07
Experience–damage		−0.25**	0.13*
Age		0.12	0.08
Gender (1 = female)		−0.05	0.08
Rent/own (1 = own)		0.07	0.15**
Income		−0.09	−0.06
Education		−0.09	−0.06
Household size		0.12	0.08
Model fit			
Chi square			52.76
AIC			22.76
$N = 187$			

3.4.3. *Social Influence Effects*

The final experimental manipulation of interest was the degree to which attitudes toward the storm expressed by others—here conveyed by actors—influenced their own attitudes and preparedness actions (Fig. 4). Paralleling the above analyses, we modeled storm concern and number of preparedness actions as a function of the valence of word-of-mouth messages for those participants who gathered this information during the task (approximately 16% of respondents). To capture a potential hypothesis that the strength of word-of-mouth effects may be conditioned by the frequency of messages, we included as a covariate the number of neighbor clips viewed with a given chapter and the interaction between valence and this number.

The results of this analysis are reported in Table IV. We find that increased expressions of calmness by neighbors—even actors observed in video clips—had the predicted spillover effect of reducing both concern about the storm and the number of preparedness actions undertaken by participants. The nature of this effect, however, differed depending on the number of neighbors who were viewed. As shown in Fig. 11, when neighbors expressed anxiety about the storm, participants displayed an elevated level of concern that was independent of the number of video clips that they viewed. In contrast, when neighbors expressed calmness, participants displayed a deflated level of concern when viewing a single clip, but ratings of concern (worry and hurricane likelihood) increased the more such clips that were viewed. Although the data do not provide a direct explanation for this effect, a natural possibility is that, rather than more clips causing greater concern, the causal flow is the opposite: participants with higher inherent levels of concern *sought out* more clips, searching for one who expressed similar feelings of worry. In either case, this conditional effect was manifested in the structural model of concern by the finding of a significant main effect for number of neighbors, a significant neighbors-by-calmness interaction, but no significant main effect of calmness (the middle column of Table IV). In contrast, the structural model of preparedness (the right column of Table IV) revealed a single simple direct effect of neighbors' emotions that augmented the indirect effects operating through feelings of concern by participants.

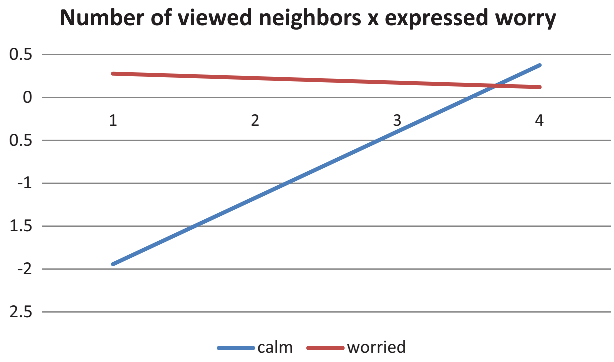

Fig. 11. Plot of the modeled interaction between the number of neighbors clips viewed and expressed worry by neighbors on latent concern (Table IV).

4. GENERAL DISCUSSION

The research was motivated by the observation that our current knowledge of how residents gather information and make decisions about imminent natural hazards is too limited to fully inform policy questions about how to improve warning communication and protective responses. The reason for this lack of knowledge is largely pragmatic: because natural hazards are infrequent, and because they do not always present a full variety of characteristics, they cannot serve alone as a natural laboratory to test all research questions of interest. In this work, we described a potential approach to overcoming this observational barrier by observing responses to *virtual* hazards experienced in web-based simulations. Specifically, we described the design of a prototype application set in the context of hurricanes. The application, *Stormview,* allows participants to gather information about a storm threat from a variety of media sources as they would in a real-world environment, and then make decisions to prepare in light of this information.

We applied *Stormview* to study the processes that underlie hurricane preparation decisions made by a sample of Florida residents. This investigation yielded a number of novel findings about how individuals gather information about storms over time and the factors that drive decisions to undertake preparation. For example, we found that the order in which participants turned to different media for information about the storm remained largely constant over time during the course of the simulation, dominated by an aggregate reliance on television, less use of the Internet, and relatively limited use of insights from peers (simulated neighbors). Although observed in the course of a simulation, it is worth noting that this overall pattern of use is similar to that which has been found in published field studies of information use in hurricanes, most notably those recently reported by Baker *et al.*,[25] Morss and Hayden,[22] and Lindell *et al.*,[14] who found a similar dominance of television, secondary reliance on the web, and a (perhaps surprising) relatively limited reliance on insights from peers as a basis for storm information.

What made the comparatively limited use of Internet information sources in the simulation notable is that, if there was a bias in the Knowledge Networks sample that constituted the study population, it is that participants would have been more computer (and Internet) savvy than the general population. Despite this presumed proclivity, on average only 43% of participants sought Internet information in a given chapter—a medium that carried far more detailed information about the storm threat than that conveyed by the television broadcast. A reasonable conclusion, therefore, is that when faced with storm threats individuals have a strong preference for gathering information from a single synthesized source that is seen as authoritative (television) rather than gathering information on their own from more detailed—but also more disaggregated—information from the web or other original sources.

An equally surprising set of results was those describing how gathered storm information became translated into decisions to take protective action. For example, we found strong evidence for a suppressing effect of negative prior storm experience; those participants who were most likely to indicate an intention to take protective action in a given chapter were those with the least prior experience with hurricanes. To clarify the finding, we should note that because we were modeling whether or not a respondent undertook an action at each of a number of time chapters, in some cases the negative effect of experience reflected a decision to *postpone* action rather than a conscious decision never to undertake it at all. For example, by the end of the simulation the vast majority (over 90%) of respondents had indicated an intention to secure food and water supplies. But even in cases where the negative effects reflected postponement, the findings still should be seen as a potential source of concern; in real-world settings where there are finite supplies of food and water, decisions to postpone preparation could have significant negative impacts.

Why did storm experience decrease expressions of concern? One hypothesis, described by Baker[12] (citing earlier unpublished work), is that preparedness may be suppressed by "false experience" effects. As we noted above, although, indeed, a large proportion of respondents had experienced hurricanes during the course of the 2004 and 2005 storm seasons, the most common experience for most would have been with the fringe effects of the storms in those years (e.g., strong gale-force winds) rather than the central core carrying the most damaging winds. A misperception that they had fully experienced each storm could have fostered a false sense of confidence about the risk such storms pose—at least to the degree of lending less urgency to the need to undertake such basic actions as stocking up on supplies.

Another surprising finding, and one with potential major policy implications, is that viewing forecast maps that depict a center track line within a cone has a positive effect on preparedness, even among those living away from the line. As we noted, maps depicting center tracks have fallen into disfavor in communication (e.g., the NHC now uses unconnected centerpoint dots in its primary forecast map product) because of prior evidence that residents, broadcasters, and emergency managers focused too much on the line when making (or recommending) preparedness decisions.[30] But missing from such critiques is the important counterfactual of whether preparedness would be increased if the only map available was one that portrayed likely movement as a homogeneous cone. The data here suggest that the answer is a clear "no": rather than making residents believe that any area within the uncertainty come may be hit, behavior is more consistent with the absence of a center track line encouraging beliefs that any area may *not* be hit. As we noted, one possible explanation is that center lines enhance beliefs that the storm will indeed be making landfall somewhere, and that as long as they remain within the cone they are likely to experience significant effects.[11]

We should emphasize, however, that the current analysis does not explore a critical aspect of the use of track lines that was the greater focus of Broad *et al.*,[30] that is, *broadcasters* focusing too much on lines when conveying storm threats to residents. In this study only 50% of respondents went to the web to view the NHC map, whereas almost all (likely mirroring the real world) viewed television broadcasts. A bias by a broadcaster (or emergency management official) thus has a greatly amplified effect on produced distorted preparatory responses.

One of the natural concerns that might be raised about findings that emerge from a simulation is that web environments—no matter how realistically designed—may produce behaviors that depart from those that would be observed in an actual hurricane. Although *Stormview* participants who were debriefed described the experience as both highly realistic and engaging, none were ever in danger of losing their home—an emotional difference that a simulation would find hard to reproduce. At the same time, evidence from applications of similar kinds of simulations in other (albeit less risky) contexts in consumer demand analysis have commonly found high levels of external validity.[24] Consistent with this, a number of aspects of participants' behavior in the simulation closely mirrored that which has been reported in field studies of responses to hurricanes. For example, as noted above, the aggregate patterns of information use revealed by participants paralleled those found in recent studies by Broad *et al.*, Morss and Hayden, and Lindell *et al.*[31,22] Similarly, in a recent "real-time" survey of the threat posed by Hurricane Earl (2010) among residents of North Carolina and Massachusetts, Baker *et al.*[31] found, much like in the *Stormview* simulation, high levels of worry and subjective probabilities of hurricane wind impacts far from the most likely point of landfall (mirrored by the lack of location effect in Table II), and, of course, the escalating degrees of worry and increased preparation as the storm approached land, a pattern also found in Hurricane Irene (2011) in New York.[32]

Although we are thus optimistic that simulations such as *Stormview* hold strong potential as a tool for understanding hurricane response behavior, their use must proceed in tandem with parallel real-world studies that would allow more detailed field validation. For example, although one might suppose that stated intentions to undertake low-cost preparation actions such as buying supplies, as revealed in *Stormview,* would closely track real-world behaviors, intentions to undertake highly costly actions such as evacuation may be overstated. A critical next step in this work is thus to develop real-world benchmarks that would facilitate recalibration of behavioral intentions revealed in simulations.

Finally, we see the *Stormview* application described here as simply a prototype that illustrates the future potential of simulations as a general methodology for studying responses to natural hazards. In future work, we hope to extend the technology used to create *Stormview* to other contexts where the process of protective decision making may be quite different than that observed for hurricanes. We suspect, for example, that social influences, particularly social media such as Twitter, will emerge as far more important when making protective decisions in response to quickly unfolding localized hazards such as wildfires or floods, where generic information channels such as television and the web are less informative about the threat posed to a given residence. Similarly, in the future we also hope to expand the scope of simulations to allow study of the effects of repeated exposure to actual and near miss encounters with hazards, a domain that is rich in policy implications but about which we know much less than we should.

ACKNOWLEDGMENTS

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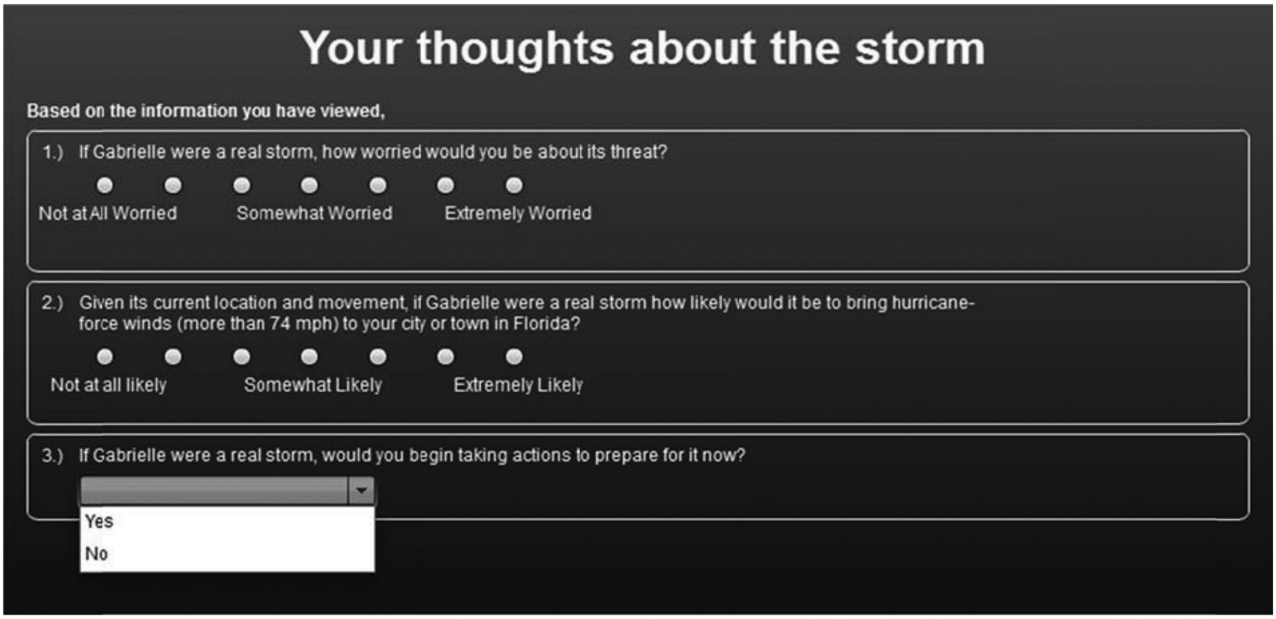
[11]Consistent with this, Broad *et al.*[30] report that some residents misconstrue the width of the cone as depicting the *size* of the storm rather than the range of uncertainty in future motion.

APPENDIX A: POSTCHAPTER SURVEY (REPEATED AT THE CONCLUSION OF EACH TIME PHASE)



Your thoughts about the storm

Based on the information you have viewed,

1.) If Gabrielle were a real storm, how worried would you be about its threat?

Not at All Worried — Somewhat Worried — Extremely Worried

2.) Given its current location and movement, if Gabrielle were a real storm how likely would it be to bring hurricane-force winds (more than 74 mph) to your city or town in Florida?

Not at all likely — Somewhat Likely — Extremely Likely

3.) If Gabrielle were a real storm, would you begin taking actions to prepare for it now?

Yes

No

If you answered, "yes", what actions would you take?

4.) Preparation for yourself:

- Travel to the store to check my supplies of water, canned foods, and batteries
- Buy extra water, food, and batteries
- Fill up my car with gas
- Get emergency cash from the bank
- Arrange for a place to stay if asked to evacuate
- Evacuate my home
- None of the Above

5.) Preparation for your Home:

- Take in lawn furniture and loose items
- Put up storm shutters
- Collect valuables and arrange for safe storage
- None of the Above

APPENDIX B: CORRELATION MATRIX OF RESPONSE AND SOCIODEMOGRAPHIC VARIABLES ACROSS CHAPTERS

	Worry	Sprob	Npreps	ExND	ExYD	Age	Gender	Rent	Income	Educa	HHSize
Worry	1	0.86	0.69	−0.06	−0.01	−0.03	0.05	0.08	−0.02	−0.05	0.04
		<.01	<.01	0.01	0.62	0.33	0.07	<.01	0.52	0.04	0.08
	1512	1512	1512	1512	1512	1445	1445	1512	1512	1512	1512
Wind prob		1	0.64	−0.04	0.02	−0.01	0.04	0.06	−0.01	0.01	0.03
			<.01	0.09	0.32	0.57	0.12	0.01	0.74	0.64	0.19
		1512	1512	1512	1512	1445	1445	1512	1512	1512	1512
Npreps			1	−0.06	−0.02	−0.06	0.1	0.16	−0.03	−0.09	0.07
				0.02	0.46	0.02	<.01	<.01	0.2	<.01	<.02
			1513	1513	1446	1446	1513	1513	1513	1513	1513
ExND				1	−0.61	−0.02	0.05	−0.04	−0.06	0.06	−0.03
					<.01	0.39	0.05	0.11	0.01	0.02	0.13
					1561	1447	1447	1561	1561	1561	1561
ExYD					1	0.17	−0.13	−0.21	0.18	0.09	−0.04
						<.01	<.01	<.01	<.01	<.01	0.06
						1447	1561	1561	1561	1561	1561
Age						1	−0.11	−0.26	0.09	0.11	−0.41
							<.01	<.01	<.01	<.01	<.01
							1447	1447	1447	1447	1447
Gender							1	0.13	−0.21	−0.05	0.04
								<.01	<.01	0.06	0.08
								1447	1447	1447	1447
Rent								1	−0.37	−0.21	0.05
									<.01	<.01	0.03
									1561	1561	1561
Income									1	0.29	0.08
										<.01	<.01
										1561	1561
Educa										1	−0.15
											<.01
											1561
HHSize											1
											1561

Key: First line: Pearson r; second line: Prob $|r|>0$ under H_0 : Rho $= 0$; third line: N
Variables:
Worry: Mean worry rating (10-point scale); Sprob: Mean probability of hurricane winds (10-point scale); Npreps: number of preparation actions (0–9); ExND: hurricane experience but no damage ExYD: hurricane experience with damage.Gender: 0 = male; 1 = female; Rent: 0 = rent; 1 = own.

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