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Toward a Multi-stage Model of Hurricane Evacuation Decision: An Empirical Study of Hurricanes Katrina and Rita

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Abstract

This study extended previous research by testing the Protective Action Decision Model (PADM) on hurricane evacuation decisions during Hurricanes Katrina and Rita. An examination of this mediation model shows that a household's evacuation decision, as predicted, is determined most directly by expected wind impacts and expected evacuation impediments. In turn, expected wind impacts and expected hydrological impacts are primarily determined by expected storm threat and expected rapid onset. Finally, expected storm threat, expected rapid onset, and expected evacuation impediments are determined by households' personal characteristics, their reception of hurricane information, and their observations of social and environmental cues. These results are generally consistent with the PADM and reinforce the importance of testing multi-stage multi-equation models of hurricane evacuation.

Keywords: Evacuation, Protective Action Decision Model, Hurricane Katrina, Hurricane Rita, Mediation effects

Introduction

Evacuation is an effective response to hurricanes (Baker 1991; Dash and Gladwin 2007) and other emergencies (Sorensen 2000; Sorensen and Sorensen 2007), but most evacuation research has focused on direct effects of each predictor on evacuation decisions and overlooked the possibility that the effects of some variables are meditated by others (Lindell 2012). Huang et al. (2012) did conduct such a mediation analysis of the response to Hurricane Ike, but there is some indication that many risk area residents failed to take this hurricane seriously (Morss and Hayden 2010; Wei, Lindell and Prater 2014). The storm only had Category 2 wind speed so people seem to have underestimated the hydrological threats from coastal surge and inland flooding (De Young et al. in press). Consequently, the Huang et al (2012) model might not generalize to major hurricanes of Category 3-5.

To better understand household evacuation decisions, the present study tested a comprehensive model of the causal relationships among variables that have only been studied previously as predictors. A mediation analysis can examine whether one variable—independent variable, *X*—influences evacuation decision—dependent variable, *Z*—via another variable—mediator variable, *Y* (Huang et al. in press; Lindell 2008; MacKinnon, Fairchild and Fritz 2007). The present study begins by summarizing the most important predictors of evacuation decisions and then tests the Huang et al. (2012) formulation of the Protective Action Decision Model (PADM—Lindell and Perry 1992, 2004, 2012) using data from Hurricanes Katrina and Rita, which both reached Category 5 intensity and had late-changing tracks.

Predictors for Household Evacuation Decisions

Baker (1991) found that the best predictors of household evacuation are hurricane risk area (e.g., barrier islands and other low-lying sites on the open coast or inland tidewater), official notices, mobile home residence, personal risk perceptions, and storm severity. Demographic characteristics and previous experiences had weak and inconsistent effects. More recently, Huang et al. (in press) conducted a statistical meta-analysis (SMA) that confirmed and extended Baker's findings. Hurricane risk area, official warnings, expected personal impacts, and observed environmental/social cues were consistent across studies in producing effect sizes ranging $.15 \leq r \leq .35$. Demographic characteristics and previous experiences had weaker effect sizes ($.01 \leq r \leq .09$ in absolute value), perhaps because their influence on evacuation decisions was mediated by those variables that had stronger effects.

Thus, research to date indicates that receiving an official warning, seeing peers evacuating, and expecting personal casualties affect evacuation decisions directly. The finding that reliance on peers, gender, homeownership, risk area, environmental cues, seeing businesses closing, intensity, nearby landfall, perceiving flood risk, perceiving surge risk, perceiving wind risk, and perceiving service disruptions have weaker but significant effect sizes suggests that these variables' effects on evacuation decisions are mediated by other variables. In addition, other variables—reliance on authorities, reliance on news media, age, previous experiences, unnecessary evacuation experiences, rapid onset, perceiving job disruptions, looting concerns, and evacuation expense—had nonsignificant effect sizes but those results were inconsistent among studies. Thus, more tests are required to examine whether their effects are mediated. Moreover, the nonsignificant effect sizes of property protection concerns and traffic jam concerns were based on only a few studies, so further examination of their effects is also required. Finally, the consistently nonsignificant correlations of race, marital status, household size, education, and income need further examination to see if these variables are significantly related to variables that are directly related to evacuation decisions. Thus, this study tests the model depicted in Figure 1 that is defined by 16 hypotheses, and also addresses two research questions, using data from the Hurricane Katrina and Rita evacuations.

H1: Age will be negatively related to perceived storm characteristics (expected hurricane intensity, expected nearby landfall, and expected rapid onset).

H2: Female gender will be positively related to perceived storm characteristics.

H3: Homeownership will be negatively related to perceived storm characteristics.

H4: Information sources will be positively related to perceived storm characteristics.

H5: Official warnings (hearing a hurricane watch or warning and receiving an official evacuation order) will be positively related to perceived storm characteristics.

H6: Previous hurricane experience will be positively related to perceived storm characteristics.

H7: Coastal proximity will be positively related to perceived storm characteristics.

H8: Observation of environmental and social cues (observations of environmental cues, businesses closing, and peers evacuating) will be positively related to perceived storm characteristics.

H9: "Unnecessary" evacuation experience will be positively related to perceived evacuation impediments (concern about protecting property from looters, concern about protecting property from the storm, concern about evacuation expenses, and concern about traffic jams).

H10: Perceived storm characteristics will be positively related to expected personal impacts (expected surge damage, flood damage, wind damage, household casualties, job disruption, and service disruption).

H11: Expected personal impacts will be positively related to evacuation decisions.

H12: Perceived evacuation impediments will be negatively related to evacuation decisions.

H13: When other variables are controlled in the prediction of evacuation decisions, only expected personal impacts and expected evacuation impediments will have statistically significant regression coefficients.

H14: When other variables are controlled in the prediction of expected personal impacts, only perceived storm characteristics will have statistically significant regression coefficients.

H15: When other variables are controlled in the prediction of perceived storm characteristics, age, female gender, homeownership, reliance on information sources, official warning, experience, risk area, and environmental and social cues will all have statistically significant regression coefficients.

H16: When other variables are controlled in the model of expected evacuation impediments, only "unnecessary" evacuation experience will have a statistically significant regression coefficient.

RQ1: Did households have similar evacuation rates in Katrina and Rita?

RQ2: What is the distribution of evacuation departure times in Katrina and Rita?

Insert Figure 1 about here

Methods

The Two Hurricanes

Hurricane Katrina was one of the most powerful hurricanes in the history of the Atlantic basin (NHC 2005a). The storm rapidly intensified to Category 5 on August 28, 2005, when it entered the Gulf of Mexico and gradually curved from southwest to north over the next three days. The National Hurricane Center (NHC) issued a hurricane watch at 10:00 am Central Daylight Time (CDT) on Saturday, August 27th and a hurricane warning at 11:00 pm CDT on Saturday, August 27th when the storm was a Category 3 and intensifying. Katrina made landfall close to Buras, Louisiana at 6:10 am on Monday, August 29th as a Category 3 hurricane with a storm surge of 2.4-6.7m (8-22 ft).

One month later, Hurricane Rita threatened the Texas coast. The NHC issued a hurricane watch at 4:00 pm CDT on Wednesday, September 21st and a hurricane warning at 10:00 am on Thursday, September 22nd (NHC 2005b) when the storm reached Category 5. Rita's track initially threatened Corpus Christi but gradually curved east toward Galveston and made landfall between Sabine Pass, Texas, and Johnson Bayou, Louisiana, at 02:38 am CDT on September 24th as a Category 3 hurricane with a storm surge of 1.2-2.1m (4-7 ft).

Data Collection Procedures

After receiving approval from the Texas A&M University Institutional Review Board, the Hazard Reduction & Recovery Center conducted two mail surveys beginning four months after Hurricane Katrina. The Katrina survey comprised two Louisiana parishes (Jefferson and St.

Charles) whereas the Rita survey included seven Texas counties. The Texas sample comprised two coastal counties from the Sabine Study Area (SSA—Orange and Jefferson), three inland SSA counties (Newton, Jasper, and Hardin), one coastal county from the Houston/Galveston Study Area (GSA—Galveston), and one inland GSA county (Harris).

Respondents were selected with a disproportionate stratified sampling procedure designed to yield 200 households in each parish or county, so the questionnaire was mailed to randomly selected households—800 in Louisiana and 2,800 in Texas. The survey generally followed Dillman's (1999) procedure; selected households were sent a packet containing a cover letter, a questionnaire, and a stamped, self-addressed reply envelope. A reminder post card was sent to those who did not return a completed questionnaire within two weeks. Replacement packets were sent at two week intervals thereafter until respondents either returned a questionnaire or received as many as one reminder post card and three questionnaire packets.

Of the 800 households in the Katrina survey, 123 had either incorrect addresses or could not be forwarded and 270 returned valid questionnaires for a response rate of 39.9% (37% in Jefferson Parish and 43% in St. Charles Parish). Moreover, 392 of 2,800 households in the Rita survey had an incorrect address or could not be forwarded but 1,007 returned a questionnaire for an overall response rate of 41.8%, which was relatively similar across counties.

Survey Instrument

The evacuation zones differed between the two Texas areas (SSA and GSA) and their evacuation zones differed from Louisiana's so comparable codes for all three coastal areas were created by coding respondents' geographic locations into five risk areas. A household was coded

0 for barrier islands, 1 for locations exposed to Category 1 or 2 hurricanes (Risk Area 1 and 2 for SSA, Zip-Zone A for GSA, and Phase I for Louisiana State), 2 for locations exposed to Category 3 hurricanes (Risk Area 3 for SSA, Zip-Zone B for GSA, and Phase II for Louisiana State), 3 for locations exposed to Category 4 or 5 hurricanes (Risk Area 4 and 5 for SSA, Zip-Zone C for GSA, and Phase III for Louisiana), and 4 for locations farther inland (Texas Department of Public Safety 2014a, b; Governor's Office of Homeland Security and Emergency Preparedness, State of Louisiana 2014).

As indicated in the Appendix, the first items in the questionnaire asked, on average, how many times per day the respondent consulted four different sources—*local authorities*, *local news media*, *national news media*, and *peers* on a five category scale of 0 times (= 1), 1-2 times (= 2), 3-4 times (= 3), 5-6 times (= 4), and 7 or more times (= 5). The second set of items asked participants to rate the extent to which they thought the storm would have three *observed storm characteristics*—nearby landfall, major intensity, and rapid onset—and six *expected personal impacts*—surge damage, inland flood damage, storm wind damage, personal casualties, job disruption, and basic services disruption. Each item was measured on a scale from not at all likely (= 1) to almost certain (= 5). The next set of items assessed the extent to which respondents considered 11 different issues when deciding to evacuate. There were three items about *environmental and social cues*, two items about *official warnings*, and four items about *perceived evacuation impediments*. There was one additional item measuring participants' *previous personal experience with hurricane storm conditions* and another item measuring respondents' *previous experience with "unnecessary" evacuation*. Each item was rated on a scale from not at all (= 1) to very great extent (= 5). Finally, respondents were asked about their *evacuation decision* using a dichotomous variable—evacuated (= 1) or not (= 0). Evacuation date was recorded from Friday August 26 to Monday August 29

(*Friday* = 1, *Saturday* = 2, *Sunday* = 3, *Monday* = 4) for Hurricane Katrina and Wednesday September 21 to Saturday September 24 (*Wednesday* = 1, *Thursday* = 2, *Friday* = 3 or *Saturday* = 4) for Hurricane Rita. The time of evacuation was measured by a 24-hour timeline beginning at 1am and ending at midnight.

Preliminary Tests

Treatment of Missing Data

Among 1,277 respondents, 719 (57.3%) completed all questions. The majority of variables had missing data rates lower than 5%, but the aggregate level of missing data across all variables might have significant impacts on the results. The results of Little's (1998, see Howell 2013) missing completely at random (MCAR) test and the Potthoff, Tudor, Pieper, and Hasselblad's (2006) missing at random plus (MAR+) test revealed that data were at least missing at random. Consequently, missing data were replaced using the Expectation-Maximization (EM) algorithm (Howell 2013).

Homogeneity of Correlations Between Hurricanes

As in Huang et al. (2012), a test of the homogeneity of the covariance matrices was conducted to justify pooling two datasets from different locations. Box's M (= 1019.13, $F_{630, 203367}$ = 1.46) was statistically significant but the extremely large number of degrees of freedom gives this test the statistical power to detect trivial levels of heterogeneity. Gnanadesikan's (1977) graphical homogeneity test shows the obtained value of each correlation for respondents from the Katrina dataset plotted against the corresponding value of that correlation for respondents from the Rita dataset (Figure 2). The cross-plot of 595—$k(k$-1)/2 = 35(34)/2—interitem correlations from the two samples is approximately linear (r = .85) and has no obvious outliers. Consequently, a pooled correlation matrix was used in subsequent analyses.

Insert Figure 2 about here

Interrater (Respondent) Agreement and Factor Analysis

Table 1 indicates that none of the variables had a level of interrater agreement r_{WG} > .50—the mid-point between a uniform distribution (r_{WG} = 0) and concentration of all values at a single point (r_{WG} = 1). This result indicates that respondents varied substantially in their perceptions of these variables. Consequently, the intercorrelations among variables and evacuation decisions are not artifactually depressed by variance restriction (Nunnally and Bernstein 1994).

Insert Table 1 about here

Next, a principal factor analysis with equamax rotation yielded a seven-factor solution in which items with factor loadings λ >.40 defined eight scales. Among perceived storm characteristics variables, nearby landfall and major intensity formed expected storm threat (ExStmThreat). Consequently, perceived storm characteristics was replaced by expected storm threat (ExStmThreat) and expected rapid onset (ExRapOnset) in H1-H8, H14, and H15.

The items in expected personal impacts loaded on two different factors, so ExHydroImpacts (surge risk and flood risk) and ExWindImpact (the remaining items) replaced expected personal impacts in H10, H11, H13, and H14. The remaining items loaded on their expected factors. Among these scales, six (ExStmThreat, ExHydroImp, ExWindImp, SocialCues, OffWarn, and ExEvacImp) reached a conventionally acceptable level of reliability ($\alpha \geq .70$, although see Schmitt, 1996, for a discussion of conventional levels of coefficient α) but NewsMedia and Exper have lower levels of reliability ($\alpha = .65$ and .57, respectively). Contact with peers and environmental cues have factor loadings $\lambda > .40$ on NewsMedia and SocialCues , respectively, but these items have distinctly different content from other items in these scales. In addition, the reliabilities of NewsMedia and SocialCues would increase if contact with peers and environmental cues were deleted from their respective scales so previous hurricane experience (HurrExper), unnecessary evacuation experience (UnnecEvac), contact with peers (Peers), and environmental cues (EnvironCues) were retained as separate variables, as were contacts with local authorities (LocAuth) and expected rapid onset (ExRapOnset).

The redefinition of some variables requires a corresponding revision of some hypotheses. H1-8 substitute expected storm threat and expected rapid onset for perceived storm characteristics and H10-12 substitute expected wind impacts and expected hydrological impacts for expected personal impacts. Moreover, H14a has expected wind impacts as the dependent variable and H14b has expected hydrological impacts as the dependent variable. Finally, H15a has expected storm threat as the dependent variable and H15b has expected rapid onset as the dependent variable.

Statistical Significance Levels

The correlation and regression analyses described in the next two sections involve a substantial number of statistical tests, so a Bonferroni correction was used to control the experiment-wise error rate. Selecting $p < .001$ level for each of 50 individual tests yields an experiment-wise error rate of $p < 05$. According to this criterion, only correlations of $r \geq .10$ are statistically significant.

Results

Respondent Characteristics

The respondents' demographic characteristics were generally consistent with the corresponding Census data (see Table 2), but the Katrina sample had a slightly higher proportion of White (77%), middle-aged (arithmetic mean, $M = 50.2$ years), married (64%), homeowners (81%) with slightly higher education ($M = 14.2$ years), lower annual income ($39,332) and larger household size ($M = 3.1$). Similarly, the Rita sample had a higher proportion White (77%), middle-aged ($M = 54.4$ years), married (71%), homeowners (89%) with higher education ($M = 14.0$ years), and lower annual income ($37,445).

Insert Table 2 about here

Hypothesis Tests: Correlation Analysis

The correlation analysis in Table 3 yielded partial support for H1 (age will be negatively related to perceived storm characteristics) and H2 (female gender will be positively related to perceived storm characteristics) because age was only significantly correlated with expected rapid onset (r = -.10) and female gender was not significantly correlated with either variable. Contrary to H3 (homeownership will be negatively related to perceived storm characteristics), homeownership was not significantly correlated with either expect rapid onset or expected storm threat.

H4 (information sources will be positively related to perceived storm characteristics), H5 (official warnings will be positively related to perceived storm characteristics), and H8 (observation of environmental and social cues will be positively related to perceived storm characteristics) were mostly supported by significant correlations of expected rapid onset and expected storm threat with contacts with local authorities (r = .12 and .12), peers (r = .14 and .10), and news media (r = .05 and .18); official warnings (r = .10 and .29); social cues (r = .22 and .21); and environmental cues (r = .13 and .28), respectively. However, H6 (previous hurricane experience will be positively related to perceived storm characteristics) and H7 (coastal proximity will be positively related to perceived storm characteristics) were only partially supported by correlations of risk area (r = -.21) and previous hurricane experience (r = .25) with expected storm threat.

H9 ("unnecessary" evacuation experience will be positively related to perceived evacuation impediments) was supported by r = .34. Moreover, as predicted by H10 (perceived storm characteristics will be positively related to expected personal impacts), expected rapid onset was correlated with expected hydrological impacts and expected wind impacts (r = .28 and .22, respectively) and expected storm threat was correlated with expected hydrological impacts and expected wind impacts (r = .38 and .53, respectively). Meanwhile, H11 (expected personal impacts will be positively related to evacuation decisions) was supported by correlations of expected hydrological impacts and expected wind impacts with evacuation decisions (*r* = .24 and .31, respectively). However, H12 (perceived evacuation impediments will be negatively related to evacuation decisions) was contradicted by a nonsignificant correlation (*r* = .02).

Insert Table 3 about here

Hypothesis Tests: Regression Analyses

H13 (predicting evacuation decision) was partially supported by Table 4 Model 1 (all displayed coefficients were re-estimated after deleting nonsignificant predictors). Specifically, expected wind impacts (*b* = .72) and expected evacuation impediments (*b* = -.34) had their hypothesized effects but, surprisingly, expected hydrological impacts, official warnings (*b* = .85), risk area (*b* = -.77), and expected rapid onset (*b* = -.33) also had significant coefficients.

Insert Table 4 about here

H14a (predicting expected wind impacts) was partially supported by Model 2, which indicates expected storm threat had a significant coefficient (β = .42) but expected rapid onset did not. Surprisingly, age (β = -.08), official warning (β = .18), environmental cues (β = .13), and expected evacuation impediments (β = .13) also had significant coefficients. H14b was partially supported by Model 3, which indicates expected rapid onset (β = .22) and expected storm threat (

β = .22) had significant coefficients but there was also significant coefficients for risk area (β = -.36) and official warning (β = .13).

H15a was partially supported by Model 4, which shows risk area (β = -.17), hurricane experience (β = .17), “unnecessary” evacuation experience (β = -.11), news media (β = .11), official warning (β = .15), and environmental cues (β = .17) had significant coefficients but age, gender, homeownership, and social cues did not. H15b was weakly supported by Model 5, which indicates social cues (β = .20) had the only predicted effect and White ethnicity (β = -.11) had an unpredicted effect.

H16 was partially supported by Model 6, which indicates “unnecessary” evacuation experience had a significant coefficient (β = .26), but education (β = -.11), income (β = -.16), social cues (β = .24), and environmental cues (β = .14) also had significant coefficients.

The regression analysis results are summarized in Figure 3, which show the two predicted paths affecting evacuation decisions. In the first path, the effects of the antecedent variables on evacuation decisions are mediated by expected storm threat and expected rapid onset, expected personal hydrological and wind impacts. In the second path, the effects of the antecedent variables on evacuation are mediated by expected evacuation impediments—although expected evacuation impediments affect evacuation decisions indirectly (via expected wind impacts) as well as directly.

However, some of the predicted regression coefficients were nonsignificant. Specifically, the coefficients for female gender and peers failed to achieve statistical significance, so these variable have been eliminated from Figure 3. Conversely, there are some significant unpredicted regression coefficients—showing that some variables whose effects were predicted to be completely mediated were only partially mediated.

Insert Figure 3 about here

Regarding RQ1, Table 5 shows hurricane evacuation rates decreased with distance from the coast. The difference was small in Louisiana (from 87.4% to 85.1%), but significantly larger in SSA (100% to 77.8%) and GSA (93.3% to 35.7%). In addition, evacuation rates in SSA (where Rita made landfall) were higher than in GSA—especially Risk Area 3 and the inland area. Even though there was a sharper decline between the risk areas and the inland area, the inland evacuation rates of 77.8% in SSA and 35.7% in GSA indicate high rates of *evacuation shadow*—evacuation in areas that were not advised to do so (Zeigler, Brunn and Johnson 1981). There were no significant difference in evacuation rates between Risk Area 2 and 3 ($\chi^2_{(1)} = .58$, $p > .05$) for Katrina, but significant differences in evacuation rates between the risk areas and the inland area ($\chi^2_{(3)} = 48.81$, $p < .001$) in SSA for Rita. Within GSA for Rita, there were significant differences in evacuation rates between the risk areas and the inland area ($\chi^2_{(4)} = 99.95$, $p < .001$) but no significant differences among the evacuation rates within the risk areas. SSA had significantly higher evacuation rates than GSA in Risk Area 3 ($\chi^2_{(1)} = 6.73$, $p < .05$) and the inland area ($\chi^2_{(1)} = 66.33$, $p < .001$).

Insert Table 10 about here

Figures 4a and 4b show respondents' evacuation departure time distributions for Katrina and Rita, respectively. Departure timing was significantly higher in daytime hours (71% left their homes between 6 am and 6 pm in Katrina and 73% in Rita) than during evening and nighttime hours (6 pm and 6 am). This effect was particularly pronounced two days (August 27) and one day (August 28) before Katrina made landfall. Similarly, the peak for Rita occurred during the daytime hours two days before landfall (September 22). Moreover, 46.3% of respondents in Katrina and 45.8% in Rita left *before* the NHC warning, 31.9% in Katrina and 31.3% in Rita left in the first 12 hours after the NHC warning, 19.2% in Katrina and 12.5% in Rita left in the second 12 hours after the NHC warning, and only 2.6% in Katrina and 10.0% in Rita began their evacuation during the storm or after it.

Insert Figure 4a and 4b about here

Discussion

The Katrina and Rita data completely support H4, H5, H8, H9, H10, and H11; partially support H1, H2, H6, H7, H12, H13, H14a, H14b, H15a, H15b, and H16; and disconfirm H3. The partial support for H1 (age negatively related to perceived storm characteristics) indicates older people were less likely to expect rapid onset but people of all ages responded similarly to expected storm threat. These findings are generally consistent with studies showing that older respondents tend to experience more hurricane evacuations but have lower risk perceptions (Huang et al. 2012; Trumbo, Lueck, Marlatt and Peek 2011). The first result is unsurprising because those who are older have had more hurricane exposure, but it is not obvious why older people were less likely to expect rapid onset.

The findings for H2 (female gender positively related to perceived storm characteristics) are consistent with coastal residents' responses in Hurricane Ike (Huang et al., 2012) because, although female gender failed to have a significant correlation with expected rapid onset, it did correlate with other risk perception measures—expected wind impacts (r = .11) and expected evacuation impediments (r = .10). These results are consistent with a wide range of previous studies finding that women are generally more sensitive to environmental threats than are men (Bateman and Edwards 2002; Davidson and Freudenberg 1996; DeYoung et al. in press). However, the mediation effects of female gender through the risk perception variables on evacuation decisions are extremely small. Specifically, the MacKinnon et al. (2007) product of coefficients procedure shows the path through expected wind impact is trivial (.11 x .30 = .03). Thus, the significant correlation of female gender with evacuation decision—which is consistent with the findings of the Huang et al. (2012) SMA—suggests that there are paths other than risk perception that need to be identified.

Contrary to H3, homeownership had nonsignificant correlations with expected rapid onset and expected storm threat. This finding is theoretically significant because many evacuation studies have reported that homeowners are less concerned about warnings and possible storm impacts, and less likely to evacuate (Huang et al. in press). Future studies need to determine if homeowners have accurate perceptions of the ability of their homes to withstand wind and water impacts and, thus, if more specific warnings about structural vulnerability are needed (cf. Morss and Hayden 2010; Wei et al. 2014).

The support for H4 (information sources positively related to perceived storm characteristics) and H5 (official warnings positively related to perceived storm characteristics) confirms that information about storm conditions was communicated through multiple information channels (Lindell et al. 2007), especially the news media (M = 3.73) and this information affected people’s threat perceptions and evacuation decisions. Interestingly, as previously reported by Lindell et al.

(2005), there were positive correlations among the information sources, so people who accessed one source tended to access other sources as well. This is consistent with previous findings that people who receive an initial warning seek to confirm it through other sources (Drabek 1986; Perry and Greene 1982) but the present study extends those results by showing that this resulted in an increase in hurricane threat perceptions and expected evacuation impediments. However, these results raise questions about the potential for conflict between information from the NHC and other sources that could cause households to delay or forego evacuation (Gruntfest, Downing and White 1978). Consequently, further research should assess the perceived characteristics (e.g., expertise, trustworthiness, and protection responsibility; Arlikatti et al. 2007) of different information sources so emergency personnel can understand how credible they are compared to other sources (Lamb et al. 2012).

The significant effects of previous hurricane experience (H6—previous hurricane experience positively related to perceived storm characteristics), risk area (H7—coastal proximity positively related to perceived storm characteristics), and environmental/social cues (H8—observation of environmental/social cues positively related to perceived storm characteristics) are also noteworthy because they confirm that people do not rely exclusively on official warnings and hurricane information transmitted through the news media. Past experience might increase people's awareness that hurricanes can rapidly intensify and change course—concerns that might be accentuated by observation of social/environmental cues. However, the effect of coastal proximity is puzzling, so further research is needed to replicate and explain these findings.

The support for H9 ("unnecessary" evacuation experience positively related to perceived evacuation impediments) suggests that memories of false alarms will discourage people from evacuating (Baker 1991; Dow and Cutter 1998). Significantly, the data indicate that "unnecessary" evacuation experience not only has the strongest effect in predicting expected evacuation impediments (β = .26), but also has a negative effect on expected storm threat (β = -.11). In addition, there are unpredicted effects of other variables on expected evacuation impediments. The negative effects of income and education suggest that households with higher socioeconomic status are less concerned about the adverse consequences of evacuation—probably because they usually have multiple transportation options, can afford to stay in hotels, and are more likely to have home insurance (Gladwin and Peacock 1997). The effects of environmental and social cues are also easy to understand; observations of neighbors evacuating and businesses closing suggest that evacuation routes will be crowded and it will be a long distance to vacant accommodations in hotels and motels.

The significant coefficients for expected rapid onset and expected storm threat on expected hydrological impacts and the significant coefficient for expected storm threat on expected wind impacts support H10 (perceived storm characteristics positively related to expected personal impacts) and the significant regression coefficient for expected wind impacts on evacuation decisions supports H11 (expected personal impacts positively related to evacuation decisions). These results suggest that NHC information about storm conditions does have its intended effect on people's expected personal impacts and, in turn, their evacuation decisions. Indeed, these results confirm the findings of the Huang et al. (in press) SMA that expected personal impact is one of the strongest and most consistent predictors of households' evacuation decisions (see also Fitzpatrick and Mileti 1993; Sorensen 2000; Sorensen and Sorensen 2007; DeYoung et al. in press). Moreover, these findings support the PADM's proposition that, once people receive a warning, they will try to determine if there is a real threat they need to pay attention to, followed by assessing their risk of personal impacts, and deciding whether to adopt a protective action (Lindell and Perry

1992, 2004, 2012). The lower level of expected hydrological impacts—M = 2.14, compared to M = 3.43 for expected wind impacts—and the smaller correlation of expected hydrological impacts with evacuation decisions are consistent with the finding that respondents were more concerned about wind threat than inland flood or storm surge threat (DeYoung et al. in press). However, this might be a result of residents believing that expected casualties, job disruption and service disruption would only be caused by wind impacts (see Table 1, Factor 3). Unfortunately, as Hurricane Ike revealed, focusing on wind impacts to the exclusion of hydrological impacts can be a major mistake (Morss and Hayden 2010; Wei et al. 2014).

The support for H12 (Perceived evacuation impediments negatively related to evacuation decisions) is consistent with Huang et al. (2012), which found expected evacuation impediments had a nonsignificant correlation coefficient but a significant regression coefficient. However, unlike the Hurricane Ike data, the Katrina/Rita data showed that perceived evacuation impediments had both direct and indirect effects on evacuation decision rather than just a direct effect. These studies appear to conflict with previous research on hurricane evacuation concluding that false alarms and other impediments have little or no effect on evacuation decisions (Baker 1991; Dow and Cutter 1998). The conflict can be resolved by noting that the Katrina/Rita and Ike studies, like the previous ones, reported nonsignificant bivariate correlations. However, the Katrina/Rita and Ike studies found significant negative coefficients in regression analyses, which were not conducted in the previous studies. Thus, further study is needed to examine the effect of "unnecessary" evacuations and other impediments (e.g., Dow and Cutter 1998; see also Dillon and Tinsley 2008; Dillon, Tinsley and Cronin 2011; Tinsley, Dillon and Cronin 2012).

There was only partial support for H13 (only expected personal impacts and expected evacuation impediments will affect evacuation decision). Although expected wind impacts and expected evacuation impediments did have the largest regression coefficients, expected hydrological impacts was not significant—perhaps because storm surge is usually limited to the immediate coast—and seems to be underestimated even there. Surprisingly, however, other variables (official warnings, risk area, and expected rapid onset) also had significant coefficients. The incomplete mediation of official warnings through wind impacts might be due to people deciding to evacuate simply because officials told them to do so, even if they did not expect significant personal impacts (e.g., Baker 1991; Gladwin, Gladwin and Peacock 2001). In addition, the incomplete mediation of risk area through wind impacts might be due to people's reaction to their neighborhoods being labeled as a "risk area", also independent of any expectation of significant personal impacts. Finally, the incomplete mediation of expected storm threat through wind impacts might be due to people's reaction to the storm's category and impact proximity, again independent of any expectation of significant personal impacts. These speculations need to be tested in future research.

In addition, expected rapid onset, which usually only has slight effect on evacuation decisions (Riad, Norris and Ruback 1999; Smith and McCarty 2009), had a direct effect as well. One plausible explanation is that both Hurricanes Katrina and Rita were Category 5 storms with late-changing tracks. Thus, residents had limited time to consider whether they needed to evacuate and, at the same time, had to determine whether they could reach safety before the hurricane arrived. Consequently, some people might not have wanted to evacuate from a rapidly approaching storm because of the risk of being caught on the road, especially if there were traffic jams. Unfortunately, too few previous studies have examined the effect of expected rapid onset, so further research is needed.

The data also partially supported H14 (only perceived storm characteristics will predict expected personal impacts), which was revised to substitute expected storm threat (H14a) and expected rapid onset (H14b) for perceived storm characteristics. Although expected storm threat did have a direct effect on expected wind impacts and both expected storm threat and expected rapid onset had direct effects on expected hydrological impacts, other variables (official warning, risk area, age, environmental cues, and expected evacuation impediments) also had direct effects on expected hydrological impact, or expected wind impact, or both.

The effects of official warning and risk area on expected hydrological and wind impacts can be explained in much the same way as the effects of these variables on evacuation decisions; there might be *labeling effects* (influence by a term that is readily accessible in memory—Cialdini 2001) that operate directly on expected hydrological and wind impacts but are independent of expected storm threat and rapid onset. Similarly, age might be associated with memories of past wind impacts that are unrelated to current descriptions of a hurricane's expected intensity, nearby landfall, and speed of onset. This explanation does not seem highly plausible because, if it were the case, one would expect an effect for past hurricane experience as well. The unpredicted effect of expected evacuation impediments on expected wind impacts might be the outcome of a correlation whose causality runs in the reverse direction; that is, increased expectations of wind impacts cause increased expectations of evacuation impediments because of respondents' assumption that a more severe storm will increase the number of evacuees and, in turn, the severity of evacuation impediments. These speculations also need to be tested in future research.

The test of H15 (age, female gender, homeownership, reliance on information sources, official warning, hurricane experience, risk area, and environmental and social cues will predict perceived storm characteristics) was partially supported. Specifically, there was evidence of direct effects of risk area, hurricane experience, “unnecessary” evacuation experience, news media, official warnings, and environmental cues on expected storm threat (H15a). As noted earlier, the effect of hurricane experience is relatively easy to understand (see the discussion of H6), as are the effects of information sources (H4), official warning (H5) and environmental cues (H8). However, as also noted earlier, the effects of risk area (H7) and “unnecessary” evacuation experience (H9) are not. Moreover, there were nonsignificant effects of age, female gender, peers, local authorities, and social cues. The nonsignificance of age is consistent with the findings of Huang et al. (2012) but the nonsignificance of female gender and social cues is not; Huang et al. (2012) did not report the effects of local authorities, peers, and news media on perceived storm characteristics so no comparisons can be made for these variables. Even more puzzling are the results for the test of H15b because Table 8 revealed effects only for White ethnicity and social cues. In addition, the R^2 (= .06) for this equation was quite small. Thus, further research is needed to better understand people’s perceptions of expected rapid onset.

As predicted by H16 (only “unnecessary” evacuation experiences will predict expected evacuation impediments), this variable has a direct effect on expected evacuation impediments. However, income, education, risk area, and social and environmental cues have unpredicted direct effects. The effects of income, and education indicate that people’s personal characteristics are related to expected evacuation impediments—a finding that is consistent with the significant correlations between personal characteristics and evacuation concerns in Hurricane Ike (Siebeneck et al. 2013). It is less obvious why risk area, and social and environmental cues are directly related to expected evacuation impediments.

The answer to RQ1 (similarity of evacuation rates in Katrina and Rita) is that the evacuation patterns were similar in both hurricanes. Not only did evacuation rates decline with distance from the coast for both hurricanes, there were nonsignificant differences between GSA (which was farther from Rita's eventual landfall) and SSA (which was closer to the point of landfall). The latter finding appears to conflict with previous reports that evacuation rates decline with distance along the coast from the point of landfall and distance inland from the coast (e.g., Baker 1991; Zhang et al. 2004; Cutter et al. 2011). However, the similar evacuation rates in all risk areas and the high level of shadow evacuation in the inland area might have arisen from two important events. First, all risk areas in the SSA coastal counties received an evacuation order. Thus, it is unsurprising that Louisiana and SSA had high evacuation rates in all risk areas and SSA had a high rate in the inland area because both locations were close to the point of hurricane landfall. Second, GSA's high evacuation rates might have occurred because it had earlier been the expected point of landfall before Rita gradually shifted its track eastward toward SSA. Moreover, the Houston mayor warned everyone to evacuate who had ever previously experienced flooding, which was widespread during Tropical Storm Allison. Thus, the inland evacuation rate of 35.7% in Harris County was much higher than would otherwise be expected.

The data related to RQ2 (distribution of evacuation departure times in Katrina and Rita) show that the Katrina and Rita departure time distributions were somewhat different from Ike's. Although respondents consistently started their trips during daylight hours (72.3% in Katrina/Rita and 80% in Ike), about 24.7% delayed their departures until shortly before landfall in Ike (Huang et al. 2012) whereas less than 10% delayed that long before Katrina and Rita. A reasonable explanation is that Ike was a Category 2 hurricane when NHC issued a hurricane warning whereas Katrina and Rita were Category 5 storms when NHC warnings were issued. Not only are respondents are more likely to imagine a Category 5 hurricane as a deadly hazard and are less likely to wait for further information (Czajkowski 2011), they are also more likely to expect that evacuation routes will be clogged because of the number of vehicles in the larger evacuation zones.

This study has some important practical implications. As mentioned earlier, respondents' misconception of wind damage as more dangerous than inland flood and coastal surge is a potentially fatal mistake because the majority of deaths in Ike were due to storm surge (Morss and Hayden 2010; Wei et al. 2014). Thus, emergency managers should increase their jurisdictions' awareness of the severity of hydrological impacts.

It is also noteworthy that these data suggest respondents made their evacuation decision by the multi-source, multi-stage risk assessment process summarized in the PADM. Local authorities who understand this process are more likely to be successful in obtaining compliance with their evacuation recommendations by communicating timely and accurate information about expected personal impacts. The negative effect of evacuation impediments on evacuation decision is also noteworthy. Local governments should anticipate concerns about those perceived evacuation impediments and establish appropriate strategies for communicating the their evacuation plan provisions for minimizing those impediments. Finally, the findings regarding household evacuations being directly affected by official warnings and risk area are important because they imply that local officials can decrease shadow evacuation if they provide information that allows people to more accurately recognize their risk areas (Arlikatti et al. 2006; Zhang et al. 2004).

Of course, this study has some limitations. First, the response rate was only 41.4% (39.9% for Katrina and 41.8% for Rita). Although this is generally consistent with other HRRC mail surveys—ranging from 24.6% (Lindell et al. 2001) to 50.7% (Lindell et al. 2005)—the sample may fail to represent some specific demographic categories. However, the sample's demographic characteristics were generally consistent with the average of the values for 2000 and 2010 census data. Moreover, overrepresentation of specific demographic categories will produce bias in other variables only to the degree that demographic variables are correlated with those variables. Indeed, Table 3 shows the correlations of demographic variables with other variables are small in this sample, as well as more generally (Huang et al. in press; Lindell 2013; Lindell and Perry 2000).

Another limitation is the disconfirmation of the MAR assumption underlying the EM algorithm for estimating missing data (recall the discussion in *Treatment of Missing Data*). This could produce bias in variables with a substantial amount of missing data, the Katrina/Rita data have a relatively low level of missing data so the bias is likely to be small (Howell 2013).

In addition, the regression models only accounted for a modest percentage of variance ($.06 \leq R^2 \leq .38$), which might result from low reliabilities of single-item variables (e.g., expected rapid onset) or unmeasured causes of the dependent variables. Some potentially relevant unmeasured variables are the presence of livestock or pets (DeYoung et al. in press) and job demands (Baker 1991; Dow and Cutter 1998, 2000) but these tend to be mentioned by few respondents. Another potentially relevant variable is disagreement among household members about the need for evacuating, which might delay them to the point that it is no longer safe to leave.

The major limitation of post-storm surveys is that they are necessarily based on a nonexperimental design because it is not possible to randomly assign respondents to hurricane conditions or personal circumstances. This could bias regression coefficients (Lindell 2008). In addition, cross-sectional studies such as this cannot verify the temporal ordering of the variables in each correlation. Although it is reasonable to assume that antecedent variables such as age, risk area, and experience preceded the risk perception variables, it is not possible to definitively determine the temporal ordering among the latter.

Finally, the analyses are based on respondents' self-reports of their personal experiences and perceptions that were collected months after the evacuation. Thus, there is no direct evidence whether the recall of these perceptions might have changed during the months between the evacuation and the time the respondents completed the survey. However, Lindell et al. (2016) report evidence from other research that people's memories for events that occurred during disasters are reasonably accurate.

Conclusions

Respondents generally considered wind impacts to be more dangerous than hydrological impacts (storm surge and inland flooding)—which might be an unintentional outcome of the Saffir-Simpson hurricane intensity scale being defined in terms of wind speed. The results of the correlation and regression analyses were generally consistent with, but extended, the results of most previous hurricane evacuation studies (Baker 1991; Huang et al. in press). In addition, the results supported the Huang et al. (2012) abbreviated PADM but are somewhat more complex than it proposed. In addition, the results also suggest that environmental cues, risk area, and hurricane experience affect people's expectations of storm threat, wind impacts, and hydrological impacts as strongly as information transmitted by the NHC through the news media or official warnings. Nonetheless, some of the results conflict with the model presented by Huang et al. (2012), so further research is needed to determine whether the conflicting results can be replicated and, consequently, require revision of the model.

Overall, this study's findings confirm the need to study households' evacuation decisions as a multi-stage process tested in earlier studies (Gladwin et al. 2001; Huang et al. 2012; Mileti & Beck, 1975; Perry, Lindell and Greene 1981). In turn, this underscores a need for future studies to report not only the final regression models or even the correlation and regression coefficients of predictor variables with evacuation decisions but the entire matrix of correlations among all variables.

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References

Arlikatti, S., Lindell, M.K., and Prater, C.S. (2007). Perceived stakeholder role relationships and adoption of seismic hazard adjustments. *International Journal of Mass Emergencies and Disasters,* 25, 218-256.

Arlikatti, S., Lindell, M.K., Prater, C.S. & Zhang, Y. (2006). Risk area accuracy and hurricane evacuation expectations of coastal residents. *Environment and Behavior*, 38, 226-247.

Baker, E.J. (1991). Hurricane evacuation behavior. *International Journal of Mass Emergencies and Disasters*, 9, 287-310.

Bateman, J.M. and Edwards, B. (2002). Gender and evacuation: A closer look at why women are more likely to evacuate for hurricanes. *Natural Hazards Review*, 3, 107-117.

Cialdini, R.B. (2001). *Influence: Science and practice* (3rd ed.). Boston: Allyn and Bacon.

Cutter, S.L., Emrich, C.T., Bowser, G., Angelo, D., and Mitchell, J.T. (2011). *2011 South Carolina hurricane evacuation behavioral study*. Columbia, SC: Hazards and Vulnerability Research Institute, Department of Geography, University of South Carolina.

Czajkowski, J. (2011). Is it time to go yet? Understanding household hurricane evacuation decisions from a dynamic perspective. *Natural Hazards Review*, 12, 72-84.

Dash, N. and Gladwin, H. (2007). Evacuation decision making and behavioral responses: Individual and household. *Natural Hazards Review*, 8, 69-77.

Davidson, D.J., and Freudenburg, W.R. (1996). Gender and environmental risk concerns: A review and analysis of available research. *Environment and behavior*, *28*(3), 302-339.

DeYoung, S.E., Wachtendorf, T., Davidson, R., Xu, K., Nozick, L., Farmer, A., and Zelewitz, L. (in press). A mixed method study of hurricane evacuation thresholds: Demographic predictors for compliance to following a voluntary or mandatory order. *Environmental Hazards*.

Dillon, R.L. and Tinsley, C.H. (2008). How near-misses influence decision making under risk: A missed opportunity for learning. *Management Science*, 54, 1425-1440.

Dillon, R.L., Tinsley, C.H., and Cronin, M.A. (2011). Why near-miss events can decrease an individual's protective response to hurricanes. *Risk Analysis*, 31, 440-449.

Dillman, D.A. (1999). *Mail and internet surveys: The tailored design method* (2nd Ed.). New York, NY: Wiley.

Dow, K. and Cutter, S.L. (1998). Crying wolf: Repeat responses to hurricane evacuation orders. *Coastal Management*, 26, 237-252.

Drabek, T.E. (1986). *Human system responses to disaster: An inventory of sociological findings*. New York: Springer-Verlag.

Fitzpatrick, C., and Mileti, D.S. (1991). Motivating public evacuation. *International Journal of Mass Emergencies and Disasters*, *9*(2), 137-152.

Gladwin, H. and Peacock, W.G. (1997). Warning and evacuation: A night for hard house. In W. G. Peacock, B. H. Morrow, and H. Gladwin (Eds.), *Hurricane Andrew: Ethnicity, gender and sociology of disasters* (Chapter 4, pp. 52-74). New York, NY: Routledge.

Gladwin, C.H., Gladwin, H., and Peacock, W.G. (2001). Modeling hurricane evacuation decisions with ethnographic methods. *International Journal of Mass Emergencies and Disasters*, 19, 117-143.

Gnanadesikan, R. (1977). *Methods for statistical data analysis of multivariate observations.* New York, NY: Wiley.

Governor's Office of Homeland Security and Emergency Preparedness (GOHSEP), State of Louisiana, (2014). Louisiana Emergency Preparedness Guide. Available at http://www.lsp.org/pdf/Emergency_Guide_v46b_7-1_4p.pdf. Retrieved on 2014.

Gruntfest, E., Downing, T. and White, G.F. (1978). Big Thompson flood exposes need for better flood reaction system. *Civil Engineering* 78: 72-73.

Horney, J. A., MacDonald, P. D. M., Van Willigen, M., Berke, P. R., and Kaufman, J. S. (2010). Factors associated with evacuation from Hurricane Isabel in North Carolina, 2003. *International Journal of Mass Emergencies and Disasters*, 28, 33-58.

Howell, D.C. (2013). *Statistical methods for psychology*. (8^{th} Ed.). Belmont, CA: Duxbury Press.

Huang, S.-K., Lindell, M. K., Prater, C. W., Wu, H.-C., and Siebeneck, L. (2012). Household evacuation decision making in response to Hurricane Ike. *Natural Hazards Review*, 13(4), 283-296.

Huang, S.-K., Lindell, M. K., and Prater, C. W. (in press). Who leaves and who stays? A statistical meta-analysis of hurricane evacuation studies. *Environment and Behavior*. DOI: 10.1177/0013916515578485.

Lamb, S., Walton, D., Mora, K., and Thomas, J. (2012). Effect of authoritative information and message characteristics on evacuation and shadow evacuation in simulated flood event. *Natural Hazards Review*, 13(4), 272-282.

Lindell, M. K. (2008). Cross-sectional research. In N. Salkind (Ed), *Encyclopedia of educational psychology* (pp. 206-213). Thousand Oaks, CA: Sage.

Lindell, M.K. (2012). Response to environmental disasters. In S. Clayton (Ed.) *Handbook of environmental and conservation psychology* (pp. 391-413). New York: Oxford University Press.

Lindell, M.K. (2013). North American cities at risk: Household responses to environmental hazards. In T. Rossetto, H. Joffe and J. Adams (Eds.). *Cities at Risk: Living with Perils in the 21st Century* (pp. 109-130). Dordrecht: Springer.

Lindell, M.K. and Brandt, C.J. (1997). Measuring interrater agreement for ratings of a single target. *Applied Psychological Measurement*, *21*, 271-278.

Lindell, M. K., Lu, J. C. and Prater, C. S. (2005). Household decision making and evacuation in response to Hurricane Lili. *Natural Hazards Review*, 6, 171-179.

Lindell, M.K., and Perry, R.W. (1992). *Behavioral foundations of community emergency planning*, Washington, DC: Hemisphere.

Lindell, M.K. and Perry, R.W. (2000). Household adjustment to earthquake hazard. *Environment and Behavior*, 32, 590-630.

Lindell, M.K. and Perry, R.W. (2004). *Communicating environmental risk in multiethnic communities*, Thousand Oaks, CA: Sage.

Lindell, M.K. and Perry, R.W. (2012). The Protective Action Decision Model: Theoretical modifications and additional evidence. *Risk Analysis*, 32, 616-632.

Lindell, M.K., Prater, C. S. and Peacock, W. G. (2007). Organizational communication and decision making in hurricane emergencies. *Natural Hazards Review, 8*, 50-60.

Lindell, M.K., Prater, C.S., Sanderson, W.G., Jr., Lee, H.M., Zhang, Y., Mohite A. and Hwang, S.N. (2001). *Texas Gulf Coast Residents' Expectations and Intentions Regarding Hurricane Evacuation.* College Station TX: Texas A&M University Hazard Reduction & Recovery Center. Retrieved from www.txdps.state.tx.us/dem/downloadableforms.htm

Lindell, M.K., Prater, C.S., Wu, H-C., Huang, S-K., Johnston, D.M., Becker, J.S. and Shiroshita, H. (2016). Immediate behavioral responses to earthquakes in Christchurch New Zealand and Hitachi Japan. *Disasters*, 40, 85-111.

Little, R.J.A. (1998). A test of missing completely at random for multivariate data with missing values. *Journal of the American Statistical Association*, 83, 1198-1202.

MacKinnon D.P., Fairchild A.J., and Fritz M.S. (2007). Mediation analysis. *Annual Review of Psychology*, 58, 593–614.

Mileti, D.S. and Beck, E.M. (1975). Communication in crisis: Explaining evacuation symbolically. *Communication Research*, 2, 24-49.

Mileti, D.S. and Peek, L. (2000). The social psychology of public response to warnings of a nuclear power plant accident. *Journal of Hazardous Materials*, 75, 181-194.

Morss, R.E. and Hayden, M.H. (2010). Storm surge and ‘‘certain death’’: Interviews with Texas coastal residents following Hurricane Ike. *Weather, Climate, and Society*, 2, 174-189.

NHC—National Hurricane Center. (2005a). *Tropical Cyclone Report Hurricane Katrina 23-30 August 2005.* Available at http://www.nhc.noaa.gov/data/tcr/index.php?season=2005&basin=atl

NHC—National Hurricane Center. (2005b). *Tropical Cyclone Report Hurricane Rita 18-26 September 2005.* Available at http://www.nhc.noaa.gov/data/tcr/index.php?season=2005&basin=atl

Nunnally, J.C. and Bernstein, I.H. (1994). *Psychometric theory*, 3rd ed. New York: McGraw-Hill.

Perry, R.W. and Greene, M. (1983). *Citizen response to volcanic eruptions*. New York: Irvington.

Perry, R.W., Lindell, M.K. and Greene, M.R. (1981). *Evacuation planning in emergency management.* Lexington MA: Heath Lexington Books.

Petty, R.E. and Cacioppo, J.T. (1986). *Communication and persuasion: Central and peripheral routes to attitude change*. New York, NY: Springer-Verlag.

Potthoff, R.F., Tudor, G.E., Pieper, K.S., and Hasselblad, V. (2006). Can one assess whether missing data are missing at random in medical studies? *Statistical Methods in Medical Research*, 15, 213-234.

Prater, C.S., Wenger, D.E. and Grady, K. (2000). *Hurricane Bret post-storm assessment: A review of the utilization of hurricane evacuation studies and information dissemination*. College Station, TX: Hazard Reduction & Recovery Center, Texas A&M University.

Riad, J.K., Norris, F.H., and Ruback, R.B. (1999). Predicting evacuation in two major disasters: Risk perception, social influence, and access to resources. *Journal of Applied Social Psychology*, 29, 918-934.

Schmitt, N. (1996). Uses and abuses of coefficient alpha, *Psychological Assessment*, 8, 350–353.

Siebeneck, L.K., Lindell, M.K., Prater, C.S., Wu, H.C. and Huang, S.K. (2013). Evacuees' reentry concerns and experiences in the aftermath of Hurricane Ike, *Natural Hazards*, 65, 2267–2286.

Smith, S.K. and McCarty, C. (2009). Fleeing the storm(s): An examination of evacuation behavior during Florida's 2004 hurricane season. *Demography*, 46, 127-145.

Sorensen, J.H. (2000). Hazard warning systems: Review of 20 years of progress. *Natural Hazards Review*, 1(2), 119-125.

Sorensen, J.H. and Sorensen, B.V. (2007). Community processes: Warning and evacuation. In H. Rodriguez, E. Quarantelli, and D. R. Russell (Eds), *Handbook for disaster research* (pp. 183-199). New York, NY: Springer.

Stein, R.M., Dueñas-Osorio, L. and Subramanian, D. (2010). Who evacuates when hurricanes approach? The role of risk, information and location. *Social Science Quarterly*, 91, 816-834.

Texas Department of Public Safety. (2014a). Hurricane evacuation maps: Houston-Galveston Study Ares. Available at https://www.txdps.state.tx.us/dem/documents/plansHurricaneMaps/HGAC_2014_zipzone.pdf. Retrieved on 2014.

Texas Department of Public Safety. (2014b). Hurricane evacuation maps: Lake Sabine Study Ares. Available at https://www.txdps.state.tx.us/dem/documents/plansHurricaneMaps/hurr_map_ssa.pdf. Retrieved on 2014.

Tinsley, C.H., Dillon, R.L. and Cronin, M.A. (2012). How near-miss events amplify or attenuate risky decision making. *Management Science*, 58, 1596–1613.

Trumbo, C., Lueck, M., Marlatt, H., and Peek, L. (2011). The effect of proximity to Hurricanes Katrina and Rita on subsequent hurricane outlook and optimistic bias. *Risk Analysis*, *31*(12), 1907-1918.

Wei, H.-L., Lindell, M.K., and Prater, C.S. (2014). "Certain death" from storm surge: A comparative study of Hurricanes Rita and Ike. *Weather, Climate and Society*. *6*, 425-433.

Zeigler, D., Brunn, S. and Johnson, J. (1981). Evacuation from a nuclear technological disaster. *Geographical Review*, 71, 1-16.

Zhang, Y., Prater, C.S., and Lindell, M.K. (2004). Risk area accuracy and evacuation from Hurricane Bret. *Natural Hazards Review*, 5, 115-12.

Table 1

Interrater Agreement (r_{WG}), Principal Axis Factors, and Scale Reliabilities

Variable	r_{WG}	Factors 1	2	3	4	5	6	7	Scale α
1.LocAuth	.49*	.08	.15	.03	.02	.14	.31	.06	
2.Peers	.12	.13	.29	-.03	.11	.07	.47	.01	
3.LocNews	.18*	-.02	-.01	.13	.08	.01	**.71**	.10	
4.NatNews	.11	.07	.03	.06	.09	.02	**.63**	.06	
NewsMedia (Item 3-4)									.65
5.ExRapOnset	.45*	.17	.16	.11	-.09	.39	.07	-.01	
6.NearbyLand	.09	-.02	.13	**.60**	.10	.25	.08	.15	
7.Intensity	.23*	-.03	.08	**.54**	.14	.19	.11	.12	
ExStmThreat (Item 6-7)									.70
8.SurgeRisk	.18*	-.04	.01	.18	.22	**.64**	.01	.20	
9.FloodRisk	.23*	.01	.07	.17	.18	**.65**	.08	.11	
ExHydroImp (Item 8-9)									.70
10.WindRisk	.22*	.22	.05	**.53**	.39	.35	.10	.02	
11.Casualties	-.02	.14	.08	**.41**	.52	.29	.11	.10	
12.JobDisrupt	-.15	.12	.12	**.41**	.11	.22	.09	-.01	
13.ServDisrupt	.47*	.08	.03	**.58**	.09	.10	.02	.08	
ExWindImp (Item 10-13)									.73
14.EnvironCues	-.10	.17	.41	.25	.18	.11	.11	.17	
15.BusClos	.00	.23	**.71**	.06	.10	.15	.13	.14	
16.PeerEvac	.07	.18	**.75**	.02	.23	.14	.14	.10	
SocialCues (Item 15-16)									.81
17.HearWarn	.20*	.09	.55	.15	**.45**	.03	.13	.14	
18.OffOrder	.29**	.08	.39	.08	**.57**	.04	.17	.12	
OffWarn (Item 17-18)									.75
19.HurrExper	-.06	.01	.05	.16	.13	.07	.05	**.64**	
20.UnnecEvac	.03	.25	.07	-.09	.04	.06	.06	**.57**	
Exper (Item 19-20)									.57
21.ProtLoot	-.13	**.62**	.12	.06	-.06	.07	.06	.29	
22.ProtStm	-.04	**.61**	.20	.14	-.02	.05	.12	.24	
23.EvacExp	-.23	**.73**	.11	.01	.15	.08	.10	.02	
24.TrafRisk	-.17	**.64**	.18	.03	.04	.06	.06	.11	
ExEvacImped (Item 21-24)									.79
EvaDec (Corr)		.36	-.21	-.24	-.14	.15	-.16	.27	
(Rotated)		-.07	.09	.06	.58	.10	.06	.11	

Note: Bold entries have factor loadings λ > .40 and are included in the scales listed following the group of items loading on the corresponding factor. Entries with an asterisk (*) have a significant interrater agreement (r_{WG}) at $p < .001$.
LocAuth = contacts with local authorities; Peers = contacts with peers; LocNews = contacts with local news media; NatNews = contacts with national news media; NewsMedia = contacts with news media; ExRapOnset = expected rapid onset; NearbyLand = nearby landfall location; Intensity = expected hurricane intensity; ExStmThreat = expected storm threat; SurgeRisk = expected surge damages; FloodRisk = expected flood damages; ExHydroImp = expected hydrological impacts; WindRisk = expected wind damages; Casualties = perceived risk on being killed or injured; JobDisrupt = perceived risk on job disruptions; ServDisrupt = perceived risk on service disruptions; ExWindImp = expected wind impacts; EnvironCues = environmental cues; BusClos = seeing business closing; PeerEvac = seeing peers evacuating; SocialCues = social cues; HearWarn = hearing warning; OffOrder = receiving an official order; OfficialWarn = official warnings; HurrExper = hurricane experience; UnnecEvac = previous unnecessary evacuation; Exper = previous experience; ProtLoot = concern about protecting property from looters; ProtStm = concern about protecting property from the storm; EvacExp = concern about evacuation expenses; TrafRisk = concern about traffic jams; ExEvacImped = expected evacuation impediments; EvacDec = evacuation decision.

Table 2. *Descriptive Statistics for the Hurricane Katrina and Rita Samples*

Hurricane	Location	Source	Variables								
			Population / N	Age*	Female	White	Married*	HHSize	Education	Income	HomeOwner
Katrina	Overall	Census 2000	503.5K	43.41	0.52	0.70	0.52	2.59	13.12	49,666	0.66
		Census 2010	485.0K	45.33	0.51	0.65	0.49	2.59	13.29	65,663	0.65
		Survey	270	50.15	0.52	0.77	0.64	3.05	14.15	39,332	0.81
	Jefferson Parish, LA	Census 2000	455.5K	43.58	0.52	0.70	0.51	2.56	13.14	49,200	0.64
		Census 2010	432.4K	45.52	0.51	0.64	0.48	2.57	13.28	64,754	0.63
		Survey	129	49.44	0.56	0.71	0.59	3.15	14.09	38,319	0.71
	St. Charles Parish, LA	Census 2000	48.1K	41.84	0.51	0.72	0.57	2.90	12.92	54,086	0.81
		Census 2010	52.7K	43.8	0.51	0.72	0.53	2.80	13.36	73,120	0.83
		Survey	141	50.79	0.48	0.82	0.7	2.97	14.20	40,273	0.90
Rita	Overall	Census 2000	4,086.5K	40.85	0.50	0.61	0.54	2.76	13.18	55,226	0.57
		Census 2010	4,839.5K	42.00	0.50	0.65	0.51	2.86	13.31	74,014	0.59
		Survey	1008	54.43	0.51	0.77	0.71	0.74	13.96	37,445	0.89
	Orange County, TX	Census 2000	85.0K	44.13	0.51	0.88	0.60	2.65	12.67	46,875	0.77
		Census 2010	82.0K	45.93	0.50	0.88	0.56	2.62	12.86	59,878	0.77
		Survey	160	55.49	0.50	0.85	0.73	2.63	13.82	37,014	0.89
	Jefferson County, TX	Census 2000	252.1K	43.85	0.50	0.57	0.54	2.55	12.89	45,698	0.66
		Census 2010	252.2K	44.31	0.49	0.56	0.47	2.55	13.06	58,464	0.63
		Survey	146	55.17	0.53	0.71	0.71	2.55	14.32	37,336	0.83
	Newton County, TX	Census 2000	15.1K	44.85	0.49	0.76	0.60	2.59	11.99	35,401	0.85
		Census 2010	14.4K	46.44	0.48	0.76	0.58	2.68	12.42	47,659	0.83
		Survey	125	55.98	0.53	0.70	0.70	2.75	12.94	31,250	0.90
	Jasper County, TX	Census 2000	35.6K	45.72	0.51	0.78	0.61	2.58	12.40	38,994	0.81
		Census 2010	35.8K	47.46	0.51	0.81	0.59	2.51	12.78	50,724	0.79
		Survey	149	56.03	0.51	0.79	0.68	2.93	13.26	34,366	0.92
	Hardin County, TX	Census 2000	48.1K	43.92	0.51	0.91	0.63	2.68	12.70	46,642	0.83
		Census 2010	54.8K	45.91	0.51	0.91	0.62	2.62	13.04	65,668	0.79
		Survey	160	54.13	0.53	0.85	0.66	2.63	13.48	36,799	0.93
	Galveston County, TX	Census 2000	250.2K	43.42	0.51	0.73	0.56	2.60	13.32	54,730	0.66
		Census 2010	292.0K	44.54	0.51	0.80	0.55	2.65	13.69	78,803	0.69
		Survey	141	53.26	0.43	0.75	0.77	2.86	14.56	42,460	0.86
	Harris County, TX	Census 2000	3,400.6K	40.25	0.50	0.59	0.54	2.79	13.22	56,557	0.55
		Census 2010	4,108.4K	41.48	0.50	0.64	0.51	2.90	13.32	75,317	0.57
		Survey	127	50.47	0.54	0.72	0.70	2.84	15.41	42,991	0.88

Population = number of population; N = number of respondents; Age = respondent's age; Female = respondent's gender; White = respondent's ethnicity; Married = respondent's marriage status; HHSize = household size; Education = respondent's education; Income = respondent's household income; HomeOwner = home ownership;
* Age and marital status for census data were evaluated for people who were older than 15 yrs.

Table 3

Means (M), SD, and Intercorrelations (r_{ij}) among Variables

Variable	*M*	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1.Age	53.5	15.1																						
2.Female	.51	.50	*-.12*																					
3.White	.77	.42	.05	*-.10*																				
4.Married	.69	.46	*-.09*	*-.20*	*.11*																			
5.HHSize	2.84	1.57	*-.39*	-.01	-.07	*.32*																		
6.Education	14.0	2.42	*-.15*	-.04	*.11*	*.09*	.02																	
7.Income[a]	38.1	12.7	*-.29*	*-.15*	*.24*	*.43*	*.15*	*.44*																
8.HomeOwner	.87	.33	*.16*	-.07	*.09*	*.25*	.02	.02	*.17*															
9.RiskArea	2.91	1.10	.00	.05	.01	-.04	.00	-.07	*-.11*	.06														
10.HurrExper	2.94	1.45	*.15*	-.03	.07	.01	-.03	.08	.04	.05	*-.21*													
11.UnnecEvac	2.34	1.40	.01	.01	.04	-.02	-.01	-.02	-.02	-.01	*-.14*	*.40*												
12.LocAuth	1.65	1.01	-.03	*.09*	*-.10*	.01	-.01	-.01	-.04	-.05	-.05	*.11*	.07											
13.Peers	3.24	1.33	*-.14*	*.18*	*-.13*	-.08	.07	*-.11*	-.08	-.03	.05	.07	*.12*	.27										
14.NewsMedia	3.73	1.13	-.01	.08	.01	.08	.08	.00	.05	.04	-.01	*.12*	*.10*	*.24*	*.37*									
15.OfficialWarn	3.79	1.10	-.02	*.19*	*-.11*	-.03	.02	-.08	*-.09*	-.05	*-.10*	*.23*	*.13*	*.16*	*.30*	*.22*								
16.SocialCues	3.06	1.27	-.04	*.16*	*-.14*	-.08	.02	*-.14*	*-.12*	-.07	-.03	*.16*	*.23*	*.21*	*.35*	*.17*	*.57*							
17.EnvironCues	3.57	1.48	*-.10*	*.11*	-.03	.01	.02	*-.10*	.00	-.01	-.04	*.22*	*.16*	*.14*	*.19*	*.17*	*.40*	*.49*						
18.ExRapOnset	1.69	1.05	***-.10***	**.02**	*-.14*	-.02	.07	-.06	-.03	**-.08**	**-.02**	**.04**	.08	***.12***	***.14***	**.05**	***.10***	***.22***	***.13***					
19.ExStmThreat	3.34	1.14	**-.03**	**.07**	.01	-.01	.00	.03	.03	**-.07**	***-.21***	***.25***	.04	***.12***	***.10***	***.18***	***.29***	***.21***	***.28***	*.21*				
20.ExHydroImp	2.14	1.11	*-.10*	.07	-.07	.02	.02	.04	.06	-.05	*-.43*	*.22*	*.12*	*.14*	.08	*.12*	*.26*	*.23*	*.23*	***.28***	***.38***			
21.ExWindImp	3.43	.98	*-.11*	*.11*	-.02	.03	.06	-.05	.00	-.02	*-.17*	*.23*	*.09*	*.13*	*.17*	*.22*	*.39*	*.31*	*.37*	***.22***	***.53***	*.47*		
22.ExEvacImped	2.97	1.18	-.01	*.10*	*-.11*	-.06	.00	*-.23*	*-.24*	-.02	.03	*.17*	***.34***	*.16*	*.21*	*.14*	*.28*	*.40*	*.30*	*.22*	*.13*	*.13*	*.28*	
23.EvacDec	.83	.38	-.06	*.11*	-.02	-.01	.04	-.01	-.02	-.05	*-.26*	*.14*	*.10*	.06	*.13*	*.11*	*.38*	*.21*	*.20*	-.04	*.20*	***.24***	***.31***	**.02**

Note: Italicized correlations are significant at $p < .001$.

Bold correlations test Hypotheses 1-12

Age = respondent's age; Female = respondent's gender; White = respondent's ethnicity; Married = respondent's marriage status; HHSize = household size; Education = respondent's education; Income = respondent's household income; HomeOwner = home ownership; RiskArea = respondent's risk area; HurrExper = hurricane experience; UnnecEvac = previous unnecessary evacuation; LocAuth = contacts with local authorities; Peers = contacts with peers; NewsMedia = contacts with news media; OfficialWarn = official warnings; SocialCues = social cues; EnvironCues = environmental cues; ExRapOnset = expected rapid onset; ExStmThreat = expected storm threat; ExHydroImp = expected hydrological impacts; ExWindImp = expected wind impacts; ExEvacImped = expected evacuation impediments; EvacDec = evacuation decision.

[a] $1,000 USD.

Table 4

Prediction of Evacuation Decision, Expected Wind Impacts, Expected Hydrological Impacts, Expected Storm Threat, Expected Rapid Onset, and Expected Evacuation Impediments

Dependent Variable	Model 1			Model 2			Model 3			Model 4			Model 5			Model 6		
	Evacuation Decision			Expected Wind Impacts			Expected Hydrological Impacts			Expected Storm Threat			Expected Rapid Onset			Expected Evacuation Impediments		
Predictors	*B*	Standard error (*B*)	Exp(*B*)	*B*	Standard error (*B*)	*β*	*B*	Standard error (*B*)	*β*	*B*	Standard error (*B*)	*β*	*B*	Standard error (*B*)	*β*	*B*	Standard error (*B*)	*β*
Age	-	-	-	-.01*	.00	-.08	-	-	-	-	-	-	-	-	-	-	-	-
White	-	-	-	-	-	-	-	-	-	-	-	-	-.29*	.07	-.11	-	-	-
Education	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-.05*	.01	-.11
Income	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-.00*	.00	-.16
RiskArea	-.77*	.10	.46	-	-	-	-.36*	.02	-.36	-.17*	.03	-.17	-	-	-	-	-	-
HurrExper	-	-	-	-	-	-	-	-	-	.14*	.02	.17	-	-	-	-	-	-
UnnecEvac	-	-	-	-	-	-	-	-	-	-.09*	.02	-.11	-	-	-	.22*	.02	.26
NewsMedia	-	-	-	-	-	-	-	-	-	.11*	.03	.11	-	-	-	-	-	-
OfficialWarn	.85*	.09	2.35	.16*	.02	.18	.13*	.02	.13	.16*	.03	.15	-	-	-	-	-	-
SocialCues	-	-	-	-	-	-	-	-	-	-	-	-	.16*	.02	.20	.22*	.03	.24
EnvironCues	-	-	-	.09*	.02	.13	-	-	-	.13*	.02	.17	-	-	-	.10*	.02	.14
ExRapOnset	-.33*	.08	.72	-	-	-	.23*	.03	.22	-	-	-	-	-	-	-	-	-
ExStmThreat	-	-	-	.36*	.02	.42	.22*	.02	.22	-	-	-	-	-	-	-	-	-
ExHydroImp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ExWindImp	.72*	.10	2.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
ExEvacImped	-.34*	.09	.71	.11*	.02	.13				-	-	-	-	-	-	-	-	-
Constant	.42	.49	1.52	1.27*	.13		1.59*	.14		2.17*	.16		1.41*	.14		2.71*	.20	
χ^2 / F		327.38*			159.50*			131.16*			51.25*			40.10*			103.76*	
Degrees of freedom		5			(5,1271)			(4,1272)			(6,1270)			(2,1274)			(5,1271)	
% Correct		86.3																
Cox & Snell R^2		.23																
Nagelkerke R^2 / Adj R^2		.38			.38			.33			.18			.06			.29	

Table 5

Evacuation Rates by Risk Area

Risk Area	Hurricane Katrina			Hurricane Rita					
	Louisiana			SSA			GSA		
	No	Yes	N	No	Yes	N	No	Yes	N
Barrier Island							6.7%	93.3%	30
1				0.0%	100.0%	26	5.3%	94.7%	95
2	12.6%	87.4%	135	2.2%	97.8%	137	7.4%	92.6%	27
3	14.9%	85.1%	134	5.6%	94.4%	125	23.5%	76.5%	17
Inland Area				22.2%	77.8%	410	64.3%	35.7%	98
Total	37	232	269	101	597	698	76	191	267
	13.8%	86.2%	100.0%	14.5%	85.5%	100.0%	28.5%	71.5%	100.0%