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Modeling the Social Amplification of Risk following a Terrorist Strike: Methodological Challenges

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Predicting and Modeling Public Response to a Terrorist Strike

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ABSTRACT

Understanding those factors critical to predicting public response is crucial to our ability to model the consequences of a terrorist strike in an urban area. Sixteen hypothetical damage scenarios were systematically varied according to non-terrorism vs. terrorism, explosions vs. infectious disease releases, terrorists' motives as demands to release prisoners vs. solely to instill fear, non-terrorists' motives as non-intentional vs. intentional (criminal), victims as government officials vs. tourists, non-terrorist incidents as involving no negligence vs. negligence, terrorist acts as non-suicidal vs. suicidal, and number of casualties (0, 15, 495). The setting was a local theme park. Students at a university in San Diego County were randomly assigned to different scenario conditions. For these scenarios, they were asked to address a number of questions regarding their perceptions and likely behaviors during and following an accident or terrorist strike. Results from regression modeling and Multivariate Analysis of Variance (MANOVA) indicated that terrorism and the mechanism used were most influential followed by the presence of suicide or negligence, motive, and victim. Number of casualties made little difference once these other factors were accounted for. To forecast community response, a system dynamics model was introduced that incorporated the study's survey findings. This model simulated the immediate and mid-term diffusion of fear in a community for different types of accidental and terrorist events. These findings should prove useful to those wishing to predict public response to a variety of different contingencies involving terrorism.

KEY WORDS: Terrorism, Anthrax, MANOVA, risk perception, social amplification of risk, system dynamics model,

1. INTRODUCTION

The goal of this paper is to examine factors pivotal to understanding public reaction to a terrorist strike. To this end a survey addressing perceptions of different types of events is discussed. We also describe a system dynamics model that represents the important feedback mechanisms that likely drive a community's response. Following a terrorist attack emergency response systems, information and communication channels, and social support organizations are likely to interact in a nonlinear fashion to produce a wide range of physical, social, and economic impacts (Kasperson et al., 1988; Maani & Cavana, 2000). This model simulates impacts (e.g., diffusion of fear) over a six-month period for different types of terrorist and accidental events.

This paper is motivated by practical considerations as well. Public officials, business leaders, and health care providers now feel the need to prepare for the impacts a major disaster might have on an urban community. Following the events of September 11, the Anthrax attacks during the same period, and the London and Madrid bombings individuals and organizations have become aware of their vulnerability with respect to explosions (bombing of tunnels and bridges), biological agents (smallpox, Anthrax), and radiation releases ("dirty bombs," attacks on nuclear reactors). Indeed, there is a clear need to provide researchers and practitioners with a better understanding of how a community is likely to prepare for and respond to an attack (Lasker, 2004).

1.1. Hazards Examined In Study

Hazards may be described from a number of vantage points and indeed have been examined along a variety of attributes. In this study we develop hypothetical threat scenarios that principally compare accidents to terrorism across two damage mechanisms: explosions and infectious diseases. Number of casualties, type of victim, and whether negligence or suicide was involved were manipulated as well. The setting is a local theme park.

1.2. Conceptual And Empirical Underpinnings for Study

The Social Amplification of Risk. The conceptual basis for this study is guided by the social amplification of risk framework. It is also grounded in systems thinking and modeling to be discussed shortly. The core idea behind the social amplification framework is that an accident or act of terrorism, will interact with psychological, institutional, and cultural processes in ways that may amplify (or attenuate) community response to the event (Kasperson et al., 1988). This theory contends, the effects of an accident or act of terrorism can extend far beyond the direct damages to victims, property, or environment and may result in momentous indirect impacts. When such events occur, information flows through various channels to the public and its many cultural groups. This information is interpreted largely on the basis of its interaction with the above processes. This interaction, in turn, triggers risk-related behavior. Such behavior, together with the influence of the media and special interest groups, generates secondary social and economic consequences that eventually call for additional institutional responses and protective actions (Burns et al., 1993; Burns and Slovic, 2007).

Past Studies. Many studies have investigated aspects of the social amplification framework. Investigations vary across particular disciplinary points of view and methodological approaches (Pidgeon, Kasperson, & Slovic, 2003) with applications from media and risk reporting (Freudenburg, 1996), organizational amplification and attenuation (Pidgeon, 1997; Kasperson, 1992; Freudenburg, 1992), institutional trust (Slovic, 1993, 2000), nuclear power and stigma (Flynn et al., 2001; Slovic et. al., 1991), public policy (Renn, 1998) and climate change (Leiserowitz, 2004; Leiserowitz, 2005). Much has been learned about the public perception of risk, but far less is known about the contexts under which amplification or attenuation occurs or how such amplification of risk perceptions are linked to secondary impacts (Kasperson, Kasperson, Pidgeon, & Slovic, 2003). Only limited examination of its dynamic propositions (e.g., how amplification of risk plays out to create indirect impacts that far exceed the direct effects of the event) has been successfully attempted (Burns and Slovic, 2007).

Systems Thinking. According to Maani and Cavana (2000), the modeling tools employed in systems thinking are useful for understanding dynamic complexity. Such complexity is likely to be present during times of crisis. According to Ackoff (1999), to understand community reaction to a terrorist act, attention must be placed on the interaction of the community's essential components and processes. From a policy standpoint, it is therefore highly useful to understand how change in one area affects the whole system and its parts over time. Indeed, one of the early applications of system dynamics modeling examined urban renewal policies and their counterintuitive contribution to the acceleration of inner-city decay (Forrester, 1969).

Feedback Loops. Sterman (2000) maintains that the dynamics of such a systemic response can be understood in terms of the interaction of positive (self-reinforcing) and negative (self-correcting) feedback loops, along with time and information delays and nonlinearities. The social amplification framework provides the conceptual guidance as to what processes should be modeled and how system feedback loops and delays may contribute to impacts far in excess of what one might expect based on the immediate and most tangible consequences of a terrorist act.

Positive loops are self-reinforcing and tend to amplify behaviors. Negative loops are balancing and tend to counter such change. For example, positive loops formed as the media began to follow the investigation of the Anthrax attacks in Washington, D.C and four other east coast cities. Friends and coworkers across the country were warned about this new risk and information spread rapidly through conversation. Concern and fear began to rise in most cultural groups, according to news polls at the time. Ripple effects spread around the nation as people placed heavy demands on hotlines and health care providers, brought suspicious mail to local police and fire departments, and sought vaccines and antibiotics in case of exposure. Policy surrounding bioterrorism response and preparedness plans were reviewed. Shortly, negative loops also became evident. As conversation intensified, people had fewer new people to talk with or less fresh news to talk about and so declined. Likewise, as fear spread communities intervened offering reassurance that the threat of Anthrax was not as serious as imagined (e.g., not international terrorism), was limited to a small number of areas (e.g. cities on the east coast) and was being addressed (e.g., the postal service screening mail). Fear decreased and eventually so did the volume of telephone calls to health care facilities and demands for antibiotics. However, the call for bioterrorism preparedness persists (Stein et al., 2004).

Delays and Nonlinearities. Delays between actions and consequences are also important and make public response difficult to anticipate much less manage (Senge, 1990). Despite an intensive federal investigation, it took law enforcement time to determine that international terrorism wasn't behind the Anthrax attacks. It also took time for scientists to declare the Senate Office Building free of Anthrax spores. Likewise, communities needed time to respond and offer help. Meanwhile the nation was on the alert and perceptions of risk were rising. Even after new information and reassurances became available, people needed time to adjust emotionally. Finally, the effects of terrorism are likely to be nonlinear, that is, they will not be proportional to the direct damage they cause. For example, the Anthrax attacks of 2001 were local events, unconnected to international terrorism, in which five people died. Yet, this event, in close proximity to September 11, has led to massive efforts in bioterrorist research, disaster preparedness, and the stockpiling of vaccines and antibiotics. Unexamined feedback mechanisms, delays and nonlinearities increase the likelihood of policy decisions with unintended consequences.

1.3. Overview of Study

This study intends to accomplish two goals. First we seek to examine differences in public response to non-terrorist vs. terrorist events. With this in mind, we systematically vary scenarios according to non-terrorism vs. terrorism, explosions vs. infectious diseases, terrorists' motives as demands to release prisoners vs. solely to instill fear, non-terrorists' motives as non-intentional vs. intentional (criminal), terrorist acts as non-suicidal vs. suicidal, non-terrorist incidents as involving no negligence vs. negligence, victims as government officials vs. tourists, and number of casualties (0, 15, 495). Second, we seek to illustrate how systems modeling may provide insight into how risk signals ripple through a community. Hence, we propose a preliminary systems model and provide simulation output depicting the diffusion of fear in a community.

2. DATA COLLECTION

2.1. Methods

2.1.1. Participants

One hundred and twenty-one undergraduate business students from a university in San Diego County were recruited from four different classes during September of 2004. The median age was 23 (range 21-52) with 49% being male.

2.1.2. Procedures

Participants were given a packet of survey materials and told they would be responding to 16 hypothetical scenarios or mishaps representing a mix of terrorist and non-terrorist events. They were then randomly assigned to one of six experimental conditions (described below) and asked to evaluate 16 scenarios on each of twelve survey questions shown in Table III. To control for possible order effects, half the respondents began with scenario 1 and the other half began with scenario 16. Likewise, the sequence of scenarios was scrambled so as not to suggest that some events were of more concern than others. After finishing this task they answered questions pertaining to their use of media, their trust of various information sources (e.g. local officials, clergy, health care providers, experts), the size of their circle of friends, and demographic information. At the close of the exercise they also responded to 10 questions taken verbatim from recent nationwide Gallup Polls relating to perceptions of terrorism. This was done to assess the generalizability of our findings beyond this student population. The entire task took between 60-90 minutes.

2.1.3. Experimental Design

The setting for these hypothetical scenarios was a local theme park. We used a two-by-three factorial design with 16 repeated measures (scenarios). Participants were first randomly assigned to one of two conditions in which either all the scenarios involved park negligence (for the non-terrorist events) and suicide (for the terrorist events) or none of the scenarios involved negligence or acts of suicide. Within each of these two groups participants were randomly assigned to one of three conditions in which all scenarios involved either 0, 15, or 495 casualties. These factorial combinations created six between-subjects groups for later comparison. Within each of these six groups all participants evaluated 16 scenarios that varied in the following manner. Eight events focused on terrorism (four were bomb blasts and four were Anthrax releases). Terrorist motives were either to obtain the release of prisoners or solely to instill fear. The remaining eight scenarios did not involve terrorism (four mishaps were propane tank explosions and four were infectious disease releases). The motives here were either intentional (criminal) or not intentional (accidental). In eight of the scenarios victims were government officials while in eight scenarios the victims were tourists.

To illustrate, Table I depicts the within-subjects design for the non-suicide/negligence group with 0 casualties. Within-subjects factor headings are in bold and between-subjects factor headings are italicized. For example, scenario 1 would be the first event evaluated by each participant. This event would have the following characteristics: Terrorist act, bomb blast, demands would be made for the release of political prisoners, government officials would be the target, no suicide would be involved, and no casualties would result. Whereas, scenario 2 in the non-suicide/negligence group with 0 casualties would have these attributes: Non-terrorist, release of an infectious disease by some park employee unintentionally, tourists would be the victims, no negligence by park authorities would be involved, and 0 casualties would result. The remaining 5 between-subjects groups had an identical design except with respect to the presence of suicide/negligence and level of casualties. For example, scenario 2 for a suicide/negligence group with 15 casualties would have the following characteristics: Non-terrorist, release of an infectious disease by some park employee unintentionally, tourists would be the victims, park authorities would be involved in some form of health code violation (negligence), and 15 casualties would result.

Table I. Experimental Design Describing Event Characteristics for Each of the 16 Scenarios for the Non-Suicide/Negligence and 0 Casualties Group

Scenario	**Domain**	**Mechanism**	**Motive**	**Target/Victims**	*Suicide/Negligence*	*Casualties*
1	Terrorism	Bomb	Prisoners Released	Officials	Non-Suicide	0
2	Non-Terrorism	Infectious Disease Released	Not Intentional	Tourists	Non-Negligence	0
3	Non-Terrorism	Propane tank	Not Intentional	Officials	Non-Negligence	0
4	Terrorism	Anthrax	Prisoners Released	Tourists	Non-Suicide	0
5	Non-Terrorism	Propane Tank	Intentional-Criminal	Officials	Non-Negligence	0
6	Terrorism	Anthrax	Solely to Spread Fear	Tourists	Non-Suicide	0
7	Non-Terrorism	Infectious Disease Released	Not Intentional	Officials	Non-Negligence	0
8	Terrorism	Bomb	Prisoners Released	Tourists	Non-Suicide	0
9	Non-Terrorism	Infectious Disease Released	Intentional-Criminal	Officials	Non-Negligence	0
10	Terrorism	Bomb	Solely to Spread Fear	Tourists	Non-Suicide	0
11	Non-Terrorism	Infectious Disease Released	Intentional-Criminal	Tourists	Non-Negligence	0
12	Terrorism	Bomb	Solely to Spread Fear	Officials	Non-Suicide	0
13	Non-Terrorism	Propane Tank	Intentional-Criminal	Tourists	Non-Negligence	0
14	Terrorism	Anthrax	Solely to Spread Fear	Officials	Non-Suicide	0
15	Non-Terrorism	Propane Tank	Not Intentional	Tourists	Non-Negligence	0
16	Terrorism	Anthrax	Prisoners Released	Officials	Non-Suicide	0

The sequence of scenarios depicted in Table I was purposefully chosen so as to mask our hypothesized order of perceived threat level. Our own ordering, which will be examined using multivariate procedures later in the paper, was guided by the following propositions. *Domain*: Terrorist acts will be more threatening than non-terrorist acts because they are potentially more catastrophic and unpredictable and are driven by malevolence. *Mechanism*: Infectious diseases will provoke more concern than explosions because they are unseen and their effects are delayed. *Motive* for terrorist events: The stated goal to spread fear will be more worrisome than the demand to have prisoners released because the latter gives the impression there is an opportunity for negotiation and hence to reduce the risk. *Motive* for non-terrorist events: Mishaps that are perpetrated intentionally will be more worrisome than pure accidents because the former implies some degree of wanton disregard for others' safety. *Victim*: Tourists as victims will be of more concern than government officials because the former have not volunteered to be put in harm's way and tourists may also appear more similar to the participants. *Suicide* for terrorist events: Terrorist acts involving suicide will be more threatening than those not involving suicide because the former appear more difficult to stop and imply a much higher level of commitment on the part of an adversary. *Negligence* for non-terrorist events: Mishaps involving negligence will be more threatening than those not involving negligence because the former imply a violation of public trust and portend a level of risk higher than previously thought. *Casualties:* The effect of casualties will be negligible because in the presence of other strong risk signals that predict potential exposure to harm this number may add little additional information.

2.1.4. Scenarios

There were 96 different scenarios (six between-subjects groups and sixteen scenarios within each group). Examples of six of these scenarios are shown in Table II.

Table II. Examples of the scenarios used to examine the effect of domain, mechanism, motive, victim, suicide/negligence, and casualties on perceptions (e.g., risk perception) and behaviors (e.g., avoiding public places).

Terrorism Bomb Blast (terrorism, explosion, fear as motive, suicide involved, tourists as victims, 495 casualties)

Reports are now coming out that a powerful bomb has gone off at a local theme park during unusually high attendance by tourists. An international terrorist group is claiming responsibility and promising to strike fear in the hearts of all Americans. It appears that a terrorist bent on suicide exploded the deadly bomb near a crowd of tourists. A large number of tourists have serious injuries and at least 495 have died.

Terrorism Anthrax Release (terrorism, infectious disease, release of prisoners as motive, no suicide, government officials as victims, no casualties)

Reports are now coming out that Anthrax was released 16 days ago at a local theme park during a tour by over a thousand government officials from around the state. An international terrorist group is claiming responsibility and demanding the release of several of its members who are in prison. It appears that a terrorist released the deadly infectious disease near the group of officials. A number of officials may have been exposed but no one has died.

Non-Terrorism *Unintentional* Propane Tank Explosion (non-terrorism, explosion, not intentional, negligence involved, government officials as victims, 495 casualties)

Reports are now coming out that a propane tank has exploded at a local theme park during a tour by over a thousand government officials from around the state. Authorities have ruled out foul play but are looking into the maintenance records of the tank. It appears that a faulty valve on the propane tank failed creating a massive explosion near the group of officials. Heavy fines may be issued pending an investigation. A large number of officials have serious injuries and at least 495 have died.

Non-Terrorism *Unintentional* Infectious Disease Release (non-terrorism, infectious disease release, not intentional, no negligence involved, tourist as victims, 15 casualties)

Reports are now coming out that an infectious disease was released 16 days ago at a local theme park during unusually high attendance by tourists. Authorities have ruled out foul play and have determined it to be unintentional. It appears that a recently hired food server was unconcerned about present medical symptoms and reported no illness on the application. The server unknowingly exposed the deadly infectious disease to a crowd of tourists. No fines or criminal charges have been issued. A number of tourists have been exposed and at least 15 have died.

Non-Terrorism *Intentional* Propane Tank Explosion (non-terrorism, explosion, intentional, negligence involved, tourists as victims, 495 casualties)

Reports are now coming out that a propane tank has exploded at a local theme park during unusually high attendance by tourists. Authorities have not ruled out foul play and are trying to determine if the explosion was intentional. Investigators are looking at the security precautions and maintenance records of the tank. . It appears that a faulty valve on the propane tank may have actually been rigged to fail creating a massive explosion near a crowd of tourists. Heavy fines and possible criminal charges may be issued pending an investigation. A large number of tourists have serious injuries and at least 495 have died.

Non-Terrorism *Intentional* Infectious Disease Release (non-terrorism, infectious disease release, intentional, negligence involved, tourist as victims, 0 casualties)

Reports are now coming out that an infectious disease was released 16 days ago at a local theme park during unusually high attendance by tourists. Authorities have not ruled out foul play and are trying to determine if the contamination was intentional. Investigators are looking at the security precautions and health screening procedures followed during hiring. It appears that a recently hired food server concealed present medical symptoms and reported having only the flu on the application. This illness was overlooked by management and the server may have knowingly exposed the deadly infectious disease to a crowd of tourists. Heavy fines and possible criminal charges may be issued pending an investigation. A number of tourists may have been exposed but no one has died.

2.1.5. Questionnaire

Table III. Survey Questions Addressed for Each Scenario

Risk Perceptions and Trust

1. To what degree do you *trust "first responders"* (police, firefighters, and so forth) to quickly *reduce any danger* resulting from an event like this?
2. To what degree do you *trust "government officials"* (President, Governor, Mayor, and so forth) to quickly *reduce any danger* resulting from an event like this?
3. To what degree do you feel you could *protect yourself* from an event like this?
4. To what degree would you *feel at risk* after learning of this event?

Attention to Media

5. How much time would you spend following news coverage of this event?

Your Contact and Conversations with Friends and Family

6. To what degree would you feel the need to *contact friends and family* to discuss this story after learning of this event?

Your Behavior During and Following the Event

7. To what degree would this event cause you to *worry about your safety throughout the day* until this event was resolved?
8. Assuming you were not at the theme park, which of these health care services would you *contact first for medical information* about any danger to you or your family?
9. How soon after learning of this event would you first contact the service you chose in the previous question to obtain information about any danger?
10. To what degree would not being able to reach a health care provider to obtain information about information about any danger cause you concern during such an event?
11. To what degree would you feel the need to *avoid public places* until this event was resolved?
12. To what degree would you feel the need to leave the area until this event was resolved?

Note. The scales are not shown but most have a format like that of "Trust" (*Low trust* 1 2 3 4 5 6 7 8 9 *High trust*) or "Risk" (*Low risk* 1 2 3 4 5 6 7 8 9 *High risk*). However, others list behaviors such as for "Avoidance" (would not avoid any public places; would avoid "theme parks" only; would avoid places like shopping malls, supermarkets, public transportation, as well as "theme parks"; would avoid almost all public places but would continue to go to my job; would avoid almost all public places including going to my job).

2.2. Results

2.2.1. Regression Analysis of Event Means

To better understand and predict mean perceptions of risk and trust for each of the 96 scenarios we developed linear regression models using the six variables depicted in Table I as predictors. D*omain, mechanism, motive, victim, suicide or negligence* were coded as 1 if terrorism, infectious disease, fear, tourist, and suicide or negligence were involved respectively (0 otherwise). Casualties was coded as 0, 15, or 495. The linear regression model for perceptions of risk is as follows: y (perceived risk) = 3.03 + 1.39(*domain*) + .77(*mechanism*) + .32(*motive*) + .24(*victim*) + .74(*suicide or negligence*) + .00004(*casualties*) with an R^2 = .82. These are unstandardized regression coefficients. Hence, the regression coefficient for domain implies that holding all other model variables at their current level, the mean perceived risk for terrorism is 1.39 scale points greater than for non-terrorism. In turn, the coefficient for mechanism reflects the mean risk perceptions differences for infectious disease versus explosions holding other model variables constant. Casualties was measured on a 0 to 495 scale thus in part explaining its comparatively small regression coefficient. Even so, its effect size is very small. All regression predictors were significant ($p < .001$) except casualties (p=.85) and terrorism appeared to have the largest effect on participants' perception of risk followed by the mechanism involved (infectious disease or Anthrax), suicide or negligence, motive (fear) and victim (tourist). Interestingly, once these five factors were accounted for, the number of deaths did not appear to contribute to perceptions of risk. Note that these findings support our hypotheses (in section 2.1.3.) that contend events involving terrorism, infectious disease, the spread of fear as a sole motive, tourists as victims, and suicide or negligence will have the highest perceived risk. The importance of these factors can clearly be seen by contrasting the three scenarios that had the highest mean risk perception ratings with the three scenarios that had the lowest risk perception ratings, as shown in Table IV.

Table IV. Ranking of Mean Risk Perception Based on Event Characteristics

Rank in risk	**Domain**	**Mechanism**	**Motive**	**Target/ Victims**	*Suicide/ Negligence*	*Casualties*	Mean (1–9)
1	Terrorism	Anthrax	Solely to spread fear	Tourists	Suicide	0	6.48
2	Terrorism	Anthrax	Solely to spread fear	Tourists	Suicide	495	6.42
3	Terrorism	Anthrax	Solely to spread fear	Officials	Suicide	495	6.32
94	Non-Terrorism	Propane tank	Not intentional	Tourists	Non-Negligence	0	2.71
95	Non-Terrorism	Propane tank	Not intentional	Tourists	Non-Negligence	15	2.68
96	Non-Terrorism	Propane tank	Not intentional	Tourists	Non-Negligence	495	2.62

Likewise, the regression model for perceptions of trust in first responders is as follows: y (perceived trust-first responders) = 7.05 - .36(*domain*) - .90(*mechanism*) + .03(*motive*) - .07(*victim*) - .06(*suicide or negligence*) -.00132(*casualties*) with R^2=.75. Domain, mechanism and casualties were significant predictors of trust ($p < .001$). However, here the effect size for casualties is not trivial as it was for risk perception. It appears that trust in first responders is greatest for handling explosions rather than infectious disease, non-terrorism rather than terrorism and smaller numbers of casualties (negative regression coefficients). The regression model for trust in government officials is as follows: y (perceived trust-government officials)= 5.66 + .76(*domain*) - .05(*mechanism*) + .22(*motive*) - .45(*victim*) - .0012(*suicide or negligence*) +.00012(*casualties)* with R^2=.50. Domain and victim were significant ($p < .001$) as was motive ($p = .03$). Trust in government officials is highest for events involving terrorism directed at other government officials with the stated intent to spread fear. Interestingly, the presence of suicide or negligence does not appear to predict trust for either first responders or government officials. To understand better the differences in trust expressed for first responders versus government officials we debriefed a number of participants following the exercise. They explained they felt terrorism was essentially a political event requiring local and federal intervention whereas accidents are best handled by specifically trained professionals.

We also investigated the relationship of risk perception to other participant responses. Our regression analysis indicated that perceptions of risk predicted the degree to which participants reported they would pay attention to a news story (R^2=.72), alert friends (R^2=.73), contact health care providers (R^2=.53), and avoid public places (R^2=.74) or leave the area (R^2=.57).

2.2.2. Analyzing Event Differences at the Participant Level

To better understand how participants differed in their response to these 16 scenarios we began by examining the distribution of scores for a variety of our measures. As an example, we compare the distributions of risk perception responses for different levels of domain and damage mechanism, the within-subjects factors with the largest effects in the previous section. Figure 1 compares a terrorist bombing with a non-terrorist propane tank explosion and Figure 2 compares a terrorist release of Anthrax with a non-terrorist release of an infectious disease. Notice that in both figures, there is clear upward shift in perceived risk for acts involving terrorism. However, this shift is more pronounced for explosions than for infectious disease. Figure 3 compares two non-terrorist events differing with regards to the damage mechanism involved while Figure 4 compares two terrorist events differing similarly. Observe that the release of an infectious disease is clearly perceived to pose greater risk than a propane tank explosion, however, the release of Anthrax is only slightly more worrisome than a bomb blast. Figure 5 compares the relative contribution of each hazard event to various levels of risk perception. Notice that about 70% of the highest risk ratings come from either bomb blasts or Anthrax whereas about 40% of the lowest risk ratings come from a propane tank explosion.

Consistent with our aggregate level analysis in the previous section the presence of terrorism or infectious disease greatly heightens risk perception with the largest effect coming from terrorism. However, these figures also reveal that the most of this difference comes in the realm of explosions. The comparatively low perceived risk for propane tank explosions may have a number of explanations. First, compared to infectious diseases, bomb blasts, and Anthrax the public is very familiar and comfortable with this type of risk. Second, propane tank explosions, tragic though they be, have a clear end point in terms of risk exposure. Infectious diseases may continue to spread and the threat of future terrorist acts does not end with one incident of terrorism.

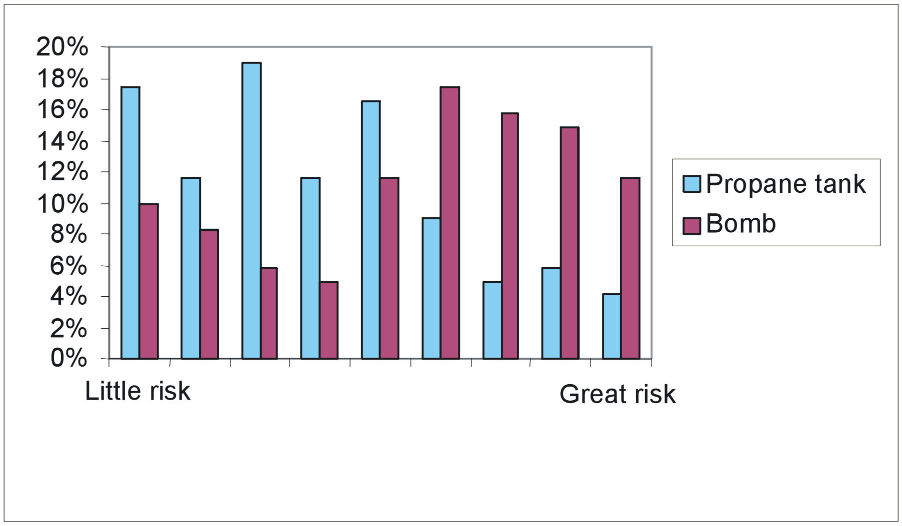

Figure 1. Comparison of Risk Perceptions for a Propane Tank Explosion (non-terrorist) versus Bomb Blast (terrorist).

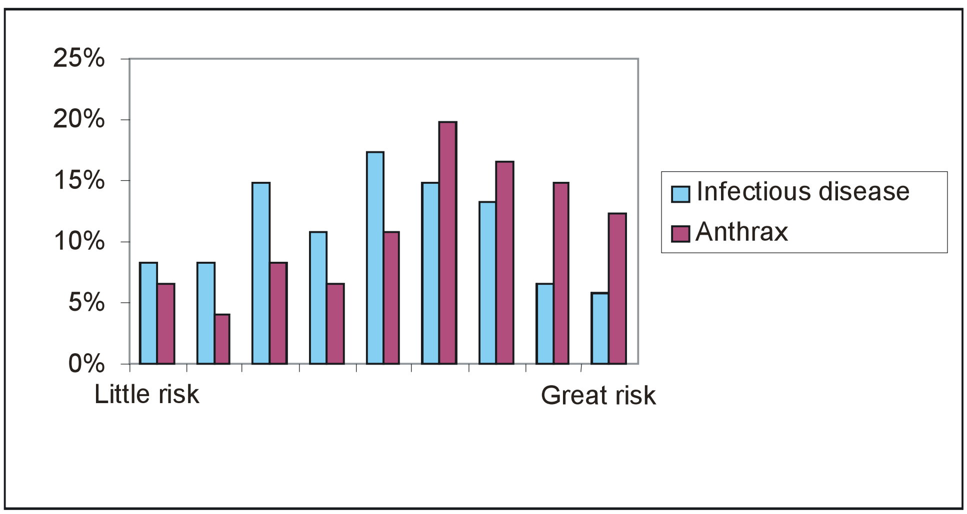

Figure 2. Comparison of Risk Perceptions for an Anthrax Release (terrorist) versus an Infectious Disease (non-terrorist).

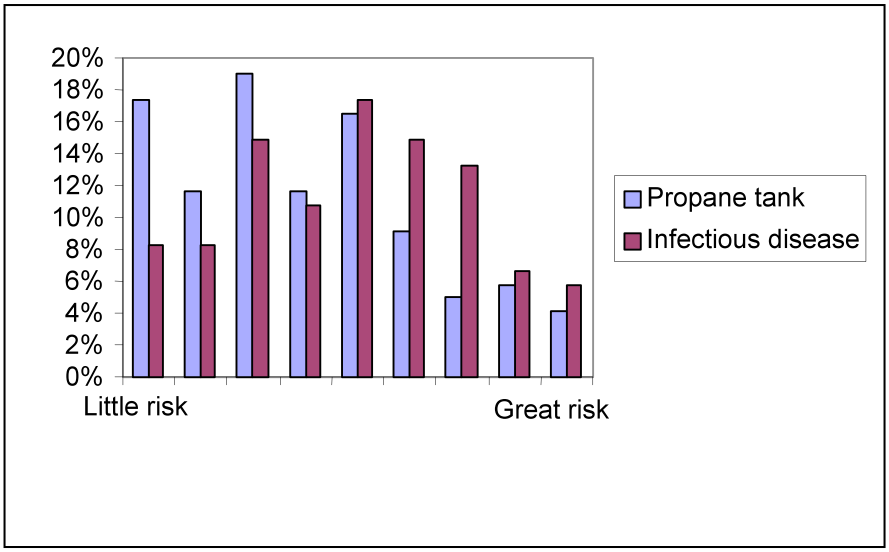

Figure 3. Comparison of Risk Perceptions for Infectious Disease Release (non-terrorist) versus an a Propane Tank Explosion (non-terrorist)

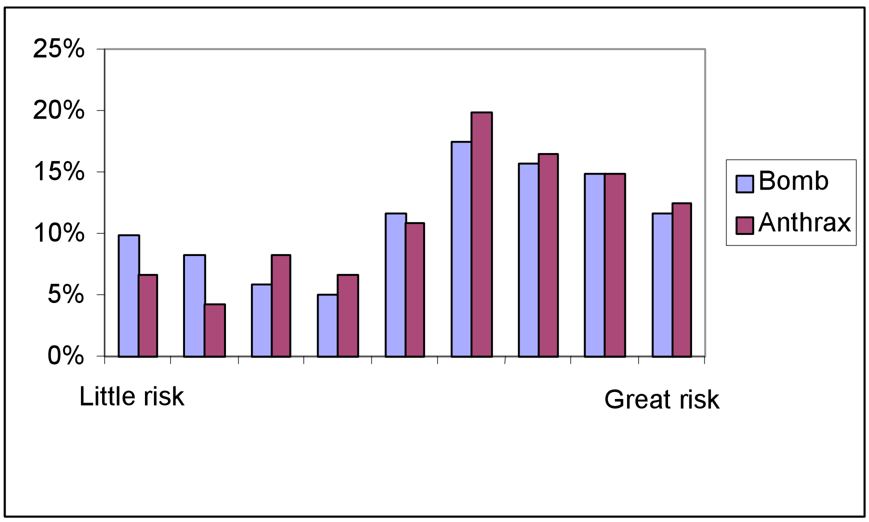

Figure 4. Comparison of Risk Perceptions for Anthrax Release (terrorist) a versus Bomb Blast (terrorist)

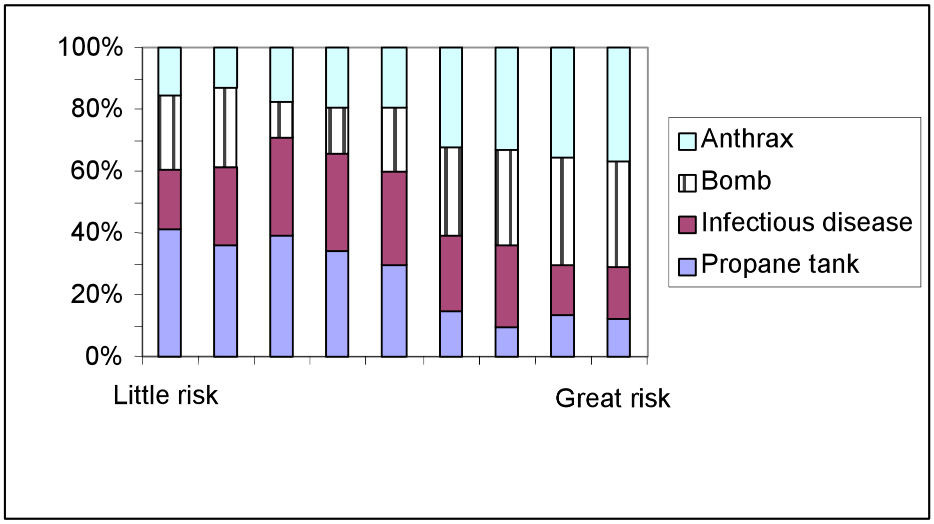

Figure 5. Comparison of the Relative Contribution (100% scale) of four events to Perceptions of Risk

2.2.3. Multivariate Analysis

In this section we further explore our hypotheses regarding the nature of the differences among the 16 scenarios. Recall (in section 2.2.1.) that we found support for our hypotheses that predicted events involving terrorism, infectious disease, the spread of fear as a sole motive, tourists as victims, and suicide or negligence would have the highest perceived risk, whereas casualties would have a negligible effect on perceived risk. These findings were based however, on applying regression analysis to event means that were averaged across participants. Willis et al. (2005) refer to this approach as an aggregate-level hazard-focused analysis. This approach had the important advantage of allowing us to examine the separate effects of each of the above six factors in a single regression model. Such modeling was not however, conducive to investigating the many potential interactions and nonlinearities among our six factors.

To address these interactions and nonlinearities, as well as look more thoroughly at trends across our 16 scenarios, we decided to examine these hypotheses without averaging across participants by conducting a Multivariate Analysis of Variance (MANOVA) using a general linear model capable of examining repeated measures in a factorial design. We felt it was important to corroborate our findings at a level closer to the participants. This approach also allowed us to examine three different effects on participant responses (e.g., risk perception): the overall within-subjects effects of *domain*, *mechanism, motive,* and *victim* across the 16 scenarios (e.g., linear, quadratic), the between-subjects effects across the six groups described previously, and the effect of gender. However, this procedure too had its limitations. In a MANOVA, repeated measures are regarded as separate within-subjects treatments. Because our scenarios were analyzed as 16 different treatments (which they were), we could not easily assess the separate contribution of domain, mechanism, motive, and victim in the manner of our more aggregate level analysis described above. Hence, both approaches proved necessary and helpful. We limit our discussion here to participants' perception of risk and intention to avoid public places.

Concerning risk perceptions, we first examined the within-subjects effects. Multivariate tests of significance (e.g., Wilks' Lamda) indicated that there were significant differences among the 16 scenarios ($p < .001$). Using multivariate contrasts we were able to further determine that these (within-subjects) scenario effects were both linear and quadratic in nature ($p < .001$) with the former effect being large and positive while the latter being small and negative. The presence of a strong positive linear effect supported our hypothesis that events such as a non-terrorist propane tank explosion that was unintentional and whose victims were government officials would be the least worrisome, a terrorist Anthrax release whose stated motive was solely to spread fear and whose target was tourists would be the most worrisome, and events such as a non-terrorist release of an infectious disease that was unintentional and whose victims were tourists would fall in between in a predicted order. The small negative quadratic effect did not contradict our hypothesis and will be discussed shortly. The interaction effects with the between-subjects factors of negligence or suicide and casualties were not significant hence these effects were consistent across the 6 between-subjects groups. Next we looked at the between-subjects effects of suicide/negligence and casualties on risk perception. Groups evaluating scenarios involving negligence (non-terrorist) or suicide (terrorist) had significantly higher perceived risk than those involving no negligence or suicide ($p = .045$), whereas groups evaluating scenarios with a larger number of casualties had no significant increase in risk perceptions was ($p = .851$). Both these findings were consistent with our hypothesis. There was no interaction effect between the two factors ($p = .918$). Gender was significantly related to risk perceptions ($p = .029$) with females having higher perceived risk.

Concerning the intention to avoid public places we found very similar results to that of risk perception. Multivariate tests indicated that there were significant differences among the 16 scenarios ($p < .001$).These effects were linear ($p < .001$) as well as quadratic ($p = .033$). Looking at the between-subjects factors, negligence or suicide was significant ($p = .022$) but casualties was not ($p = .155$). These results were also consistent with our hypothesis. Gender now was not significantly related to the intention to avoid public places ($p = .449$).

To examine the nature of these within-subjects linear and quadratic effects more closely we looked at how individual participants responded to each of the 16 scenarios in terms of risk perception and intention to avoid public places. Willis et al. (2005) refer to this approach as a participant-level hazard-focused analysis. We selected 24 participants from our sample (4 subjects from each of the six between-subjects groups) for closer evaluation. As a start, we attempted to overcome the limitation of our MANOVA by estimating the separate effects of domain, mechanism, motive, and victim on individual participant risk perceptions. To do this, risk perception scores for the 16 scenarios were regressed on domain, mechanism, motive, and victim for each participant resulting in 24 multiple regression equations. However, because of the small number of events relative to the number of parameters being estimated, our results proved unreliable (e.g., unusually large R^2s suggesting data fitting and many insignificant regression coefficients). We have guarded confidence that, domain and to some extent mechanism appeared to predict risk perceptions.

We decided to reduce the number of parameters to be estimated by coding each scenario 1 through 16 with a 1 corresponding to the hypothesized least worrisome event, a 2 relating to the next worrisome event and so forth. Regarding risk perception, for each participant we regressed their response (i.e., risk perception) for each event on the coded scenarios. We investigated a number of regression functions (e.g., linear, quadratic, power) for best fit. Consistent with the multivariate analysis we found that a quadratic function of the form $y = a + b_1x – b_2x^2$ worked well (about 75% of cases) with a median $R^2 = .45$ and 70% of the R^2s greater than .30. We also found a similar quadratic function worked well (about 67% of cases) for modeling the intention to avoid public places with a median $R^2 = .58$ and 69% of the R^2s greater than .30. Regarding risk perception for these scenarios, we estimated this regression equation to be $y = 2.30 + .36x - .010x^2$ for events involving no negligence or suicide and $y = 3.13 + .38x - .012x^2$ for events involving negligence or suicide. Other types and numbers of hazards need to be examined to determine whether this quadratic function is idiosyncratic to our scenario development and data or has a more general application. What this function suggests is that first, it may be possible to use the factors domain, mechanism, motive and victim as a guide to ranking (value of x) a set of hazardous events in terms of threat level as we did here. For example, consider a set of events ranging from an accidental explosion involving firefighters to a terrorist anthrax release involving tourists. The former would be ranked lowest and the latter would be ranked highest. All other mix of events would be ranked in between according to their scores on domain, mechanism, motive and victim with the largest weight given to domain and the smallest to victim. Second, risk perception may increase linearly with our ordering (b_1x), but will taper off slightly at the upper range of our rankings ($- b_2x^2$), that is change in risk perceptions between ranks is not equal. Understanding the nature of participants' response to our scenarios (i.e., $y = a + b_1x - b_2x^2$) was important because it would provide the input to a very influential component of our systems model to be discussed next.

3. SYSTEMS MODELING

3.1. System Dynamics Modeling

Modeling procedures. As a brief explanation of our systems modeling procedures, consider the system dynamics model shown in Figure 6. For a more complete model description see Burns and Slovic (2007). This model is a stock and flow diagram designed to track how the system changes over time. Stocks (depicted as rectangles) are accumulations and represent the state of the system at any given moment. Flows (depicted as in-flowing and out-flowing pipes) increase or decrease the size of the stocks over time, respectively. Rates of flow are regulated by valves, which in turn are influenced by causal factors (depicted as circles and their corresponding causal arrows). The clouds at the beginning and end of the pipes are stocks (sources and sinks respectively) representing variables outside the boundary of the model. A number of causal factors and arrows have been omitted to make the figure more readable, but this figure provides the general idea.

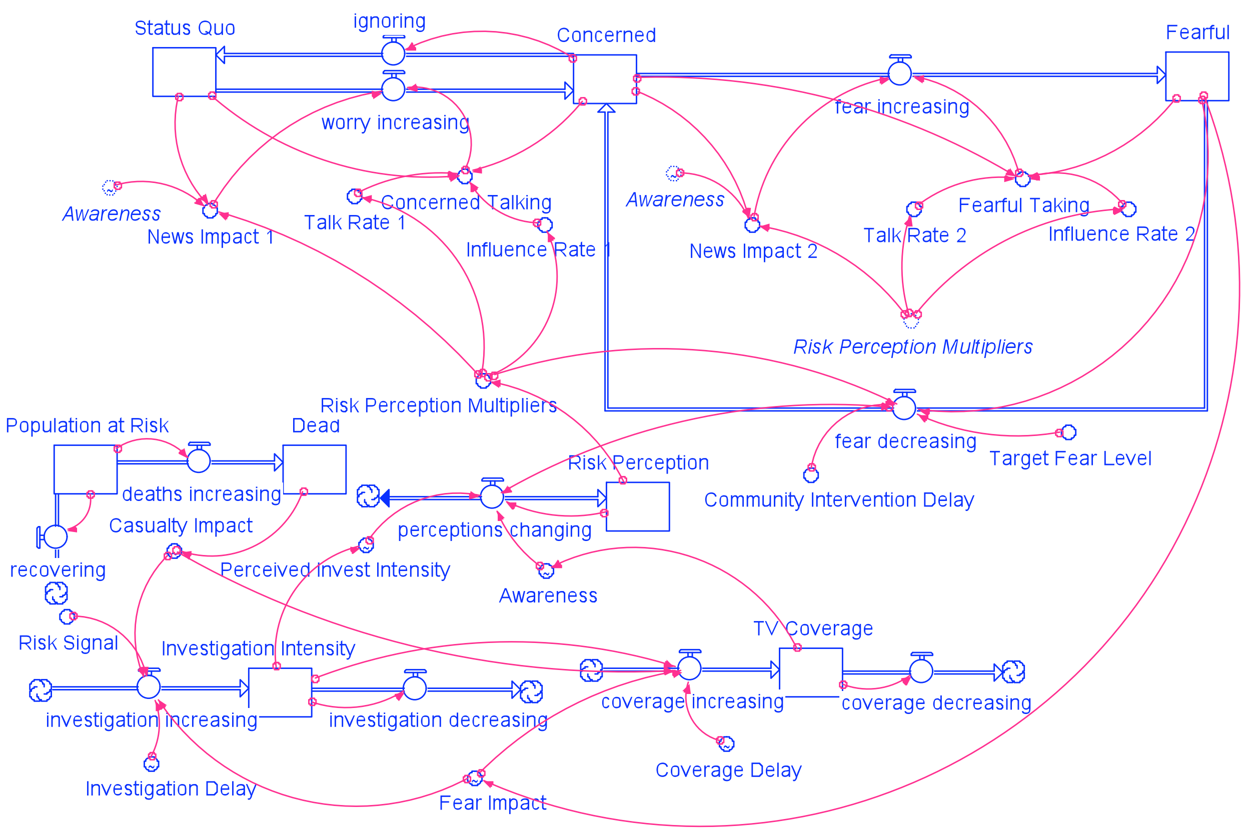

Figure 6. System dynamics model of public response to a terrorist strike (abridged).

The dynamic hypothesis underlying our model is based in part on the social amplification of risk framework, which predicts that events with higher risk signal will receive greater investigative attention and broader media coverage. It also suggests that the media may amplify this risk signal still further through sheer volume of coverage and selective content and imagery. Concerned citizens may also serve as amplifying stations through word-of-mouth and thus contribute to the rapid diffusion of fear in a community. High levels of fear may subsequently lead to costly secondary impacts as increasing demands are placed on community resources.

Concretely, the story behind the model begins with the stock "Population at Risk" in which people are in the proximity of a terrorist act and some die ("Dead "). An investigation ensues based on these deaths, the risk characteristics (e.g., Anthrax or bomb blast) of the event and subsequent fear. As the investigation intensifies ("Investigative Intensity "), media coverage ("TV Coverage ") increases and alerts citizens about the event. Increased awareness of the terrorist strike causes perceived risk to increase which in turn causes people to become concerned ("Concerned ") and alert others. Some people will also become fearful ("Fearful "). However, as the population becomes fearful the community begins to intervene and offer support and reassurance, which in turn begins to reduce the level of fear. As fear declines so does perceived risk. Eventually the community regains its equilibrium but the public remains at a higher state of concern (not shown here but was examined) than before the event.

3.2. Results

Systems Model Output. Now that our modeling and survey data have been discussed, consider the following example output (Figure 7) in which the diffusion of fear (the stock "Fearful " from Figure 6) in a community is compared for a propane tank explosion, bomb blast, and Anthrax release over a six-month period. We have construed "fearful" to be not only an expression of fear but a propensity to take protective actions such as avoiding public places. This is a simple representation of a large urban community's response to terrorism or serious accident. It assumes a population of about one million adults of which 1,000 people have been put in harm's way at a local theme park, half of whom die. It also postulates it takes much longer to investigate an Anthrax attack than a bomb blast or a propane tank explosion.

The output is based in part on our survey data as well as personal assessments of the functional relationships among a number of model variables. For example, the risk characteristics input for different types of hazardous events in Figure 6 were derived from our prediction of risk perceptions based on the event's *domain, mechanism, motive, victim, suicide/negligence* and *casualties* profile discussed earlier. Likewise, the spread of news about a possible threat via word-of-mouth is depicted by "Concerned Talking" and "Fearful Talking". These are in part a function of the average contact rate per person (*talk rate*) and the persuasiveness of each communication (*influence rate*). We were able to assign values for contact and persuasion rates based on our survey reports of an event's perceived risk, and ability to generate communication among friends, as well as the average number of friends per participant. We also assessed the relationship between a number of key model variables (for a detailed description see http://www.decisionresearch.org/pdf/TheDiffusionofFearFigureEquationsGraphs_000.pdf).

Observe, in Figure 7, that about forty five percent of citizens are predicted to be fearful even two months after an Anthrax attack. While this percentage may appear high, Snyder and Park, (2002) found in a nationwide survey two months after September 11 that 21% of people described themselves as very afraid and 23% were somewhat afraid. It's not unreasonable to think that, in terms of fear, the release of Anthrax may have a larger and more lasting impact on local residents than September 11 had on people nationwide.

Notice the marked difference in the percentage of fearful people and the length of time they remain fearful for each event. This contrast is driven initially by differences in the risk characteristics of each event as shown in Table I and the duration of investigation. As inputs to the model, casualties are the same for all three events (500) but risk perception is greater for Anthrax than for bomb blast or accidental propane tank explosion. However, the area under the curves representing number of fearful people by number of days they remain fearful is about seventy percent greater for Anthrax than for the propane tank explosion. The pronounced differences in the number of fearful people and the length of time they remain afraid has sobering implications for the physical and economic health of a community, not to mention its quality of life. This kind of amplification results from the many reinforcing feedback loops, delays, and nonlinearities predicted by the social amplification of risk framework.

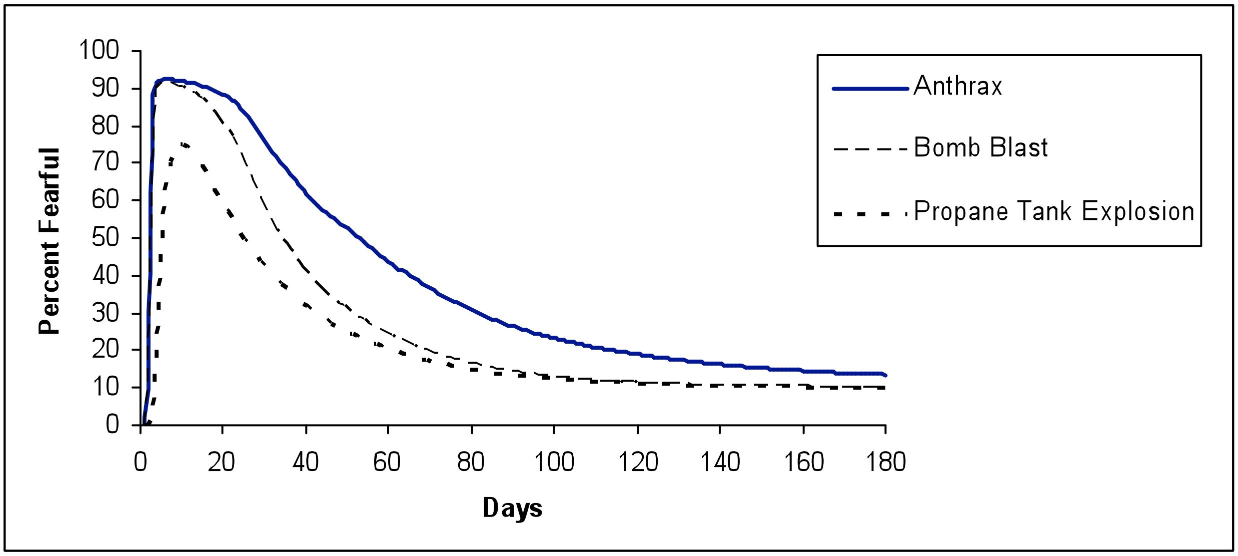

Figure 7. Simulated response for three events differing in risk signal and investigation duration.

4. DISCUSSION

4.1. Major Findings

This study has examined threat scenarios across a number of variables pertaining to perceptions and likely behaviors during and following a mishap. These threat scenarios were investigated both at the aggregate level (averaging across participants) and at the disaggregate level (at the level of participants). The study has also involved different methodological approaches (e.g., univariate regression and Multivariate Analysis of Variance). The primary findings suggest that the threat of terrorism looms large in the public's mind relative to a comparable accident. Infectious diseases provoke considerably more concern than explosions especially for non-terrorist events. The use of suicide with the expressed motive to spread fear heightens perceptions of risk. Likewise, non-terrorist incidents that involve negligence and that are motivated by criminal intent also augment concern. Who the victims are appears to matter but to a lesser extent. Once these mentioned factors are taken into account the effect of casualties on perceived risk appears negligible. These effects are primarily linear but concern appears to taper off slightly at the upper range of worrisome events (e.g., bomb blast). Similar findings were found with regards to the intention to avoid public places during or following a mishap. Females reported a greater perceived risk for the scenarios presented in this study but not a greater intention to avoid public places during such events.

Trust in first responders appears greatest for non-terrorist events involving explosions rather than infectious diseases and resulting in smaller number of casualties. Conversely, trust in government officials is greatest for terrorists' events regardless of whether they involve explosions or infectious diseases. This difference appears to be motivated by the perception that terrorism is to some extent political and hence naturally falls within the realm of government officials but accidents require the special professional skills of first responders. However it is important to note that, since this data was collected, the nation has witnessed a largely ineffective response to Hurricane Katrina on the part of public officials and some first responders (i.e. some police officers). We suspect public trust would be somewhat more guarded if measured now.

We also found that perceived risk is a good predictor of the degree to which the public will report they will alert their friends or pay attention to the media during a threatening event. It also predicts the reported propensity to avoid public places or to leave the area until the event is resolved.

Survey findings were also incorporated into a systems model to examine how fear might diffuse within a community immediately following a terrorist attack or an accident. Scenarios differing in perceptions of risk and length of investigation were simulated to determine their impact on media coverage, word-of-mouth and fear over time. Small increases of either the level of perceived risk or length of the investigation had an amplifying effect on the number of fearful people, and rate of diffusion and duration of fear. Though not the focus of this study, we also varied the level of intervention by social support institutions (not treated separately) to determine its impact on the rate at which people become less fearful. We found that high levels of intervention, especially early on, produced a noticeable decline in fear. Predicted public response was dramatically different for accidents versus terrorist events, a finding consistent with the social amplification of risk framework. This study begins to demonstrate how responses to carefully designed scenarios can provide data and parameters for input into our system dynamics model.

4.2. Study Limitations

One-hundred-twenty-one students were recruited at a university in the San Diego area during September of 2004. Surveying only students raises questions about the generalizability of our findings beyond a college setting. To address this issue we had participants also respond to recent Gallup Poll questions pertaining to terrorism (e.g., "How worried are you that you or someone in your family will become a victim of terrorism?") to compare their attitudes and perceptions to responses in a representative national sample. Student answers to these questions were very similar to the Gallup Poll results published in August 2004 suggesting that our participants' responses may be typical of the general population. This study also took place very near to the anniversary of 911 and also during the last few months of a presidential campaign in which terrorism was a major issue. As a result, participants' awareness and level of concern about terrorism may have been higher than is typical for them. While our findings may somewhat overestimate public reaction to certain types of hazards, the timing of the study also tended to encourage participants to treat the exercise more seriously as evidenced by the amount of time they devoted to the task and quality of their responses. In terms of our design, we decided to treat casualties as a between-subjects factor which may in part have accounted for its negligible effect size. However, we also treated suicide/negligence as a between-subjects factor and its effect size was quite large. This was a moderately small sample as well, which posed certain estimation challenges. Most notably our ability to detect higher order factor interactions was not very high (none appeared to be statistically significant but this may be due to low power as well). However, because of the statistical efficiency of our experimental design the main effects we report have very high precision (power calculations above .95).

Our model attempts to represent some of the dynamics likely to drive public response to a variety of hazardous events. Model construction was guided by the social amplification of risk framework. However, many of the functional relationships between model variables were based on reasonable but subjective assessments. For example, we know that social support groups and institutions engage the public during a crisis, but we had to subjectively predict the extent, timing, and effectiveness of their response? Hence, it would be helpful to corroborative these findings with behavioral data from other terrorist attacks or major disasters. We did compare the level of fear predicted by our model 60 days after an Anthrax attack with national surveys that tracked public perceptions following September 11 and found our projections reasonably close. Likewise, we have incorporated a number of important variables but some were not included. For example, we did not model the impact of government response. However, this response most probably would influence not only the behavior of the media, public and various institutions but impact the magnitude of the event itself. Finally, several of the variables in our systems model are really an aggregate of a number of related variables. This was done for simplicity but these components may not always behave as an aggregate. For example, "Investigative Intensity" represents the efforts of first responders, and local and federal authorities. However, a propane tank explosion might require intense efforts by first responders and local authorities whereas a terrorist threat may involve nationwide attention from a number of groups.

4.3. Policy Implications

Policy makers need to prepare for a wide range of threatening events to their communities and the nation. Terrorist acts are likely to spark rapid and prolonged concern as the public learns to cope with the crisis. Conversely, non-terrorist explosions (non-nuclear at least) and natural disasters also have the potential to kill or injure large numbers of people, but events of this kind have a natural closure-it's reasonable to say the area is now safe or the storm is over. Here, it is possible to communicate what happened and why. It is also feasible to tabulate who has been injured and to what extent. In short, it's possible to begin resuming normal activities. Terrorist events are different. Is it reasonable to say the event is over? Is it possible to adequately explain why the attack took place? In the case of a biological, chemical, or radiological attack, can we say in the short term, who has been effected and to what extent? The crisis subsides to be sure, but it is unlikely to be fully resolved. We in time make an uneasy truce with the situation and get back to our lives-not entirely unchanged however. For these reasons terrorism presents a unique challenge to officials wishing to mitigate the effects of a terrorist strike in a community.

Our survey findings suggest that the public may have moderate trust in government officials' ability to reduce the danger during a terrorist event but only limited confidence in first responders' capability to effectively handle such a crisis, especially if it involves infectious diseases. Clearly government officials should play a more visible role in communicating with the public about precautions being taken and coordinating the response during a terrorist incident. Additionally, first responders should consider more actively engaging the community in a variety of terrorism simulations to help engender trust and foster communication with the public. Results from our simulation suggest that the longer the crisis goes unresolved in terms of investigative closure the more opportunity there is for the risk signal to amplify and for fear to spread throughout the community. Likewise, the greater the level of fear in the community the greater the effort required to restore normalcy among the public. Conversely, intervention by social support groups and institutions can help restore normalcy. These findings speak to the need for a careful, coordinated and rapid response on the part of government officials, first responders, and community leaders and support groups. An active effort should be made in advance to search for any and all delays in the community's delivery of health care, financial assistance, and social support.

4.4. Suggestions for Future Research

4.4.1. Data Collection

In this paper we have focused on hazards that have involved either explosions or infectious diseases. However, it would be very helpful to extend this study to other types of damage mechanisms such as chemical and radiological explosions as well as natural disasters. Natural disasters are especially important because a great deal of behavioral data has been collected following hurricanes, tornados, and floods. Comparing survey responses to natural disaster scenarios with reports of actual behaviors gathered in the field would serve as a useful benchmark to other types of disasters in which behavioral data is rare. Additionally, the setting here was a theme park, but of more general interest would be to couch these scenarios in terms of damage to our transportation, communication, energy, water or cyber systems. These systems are important because damage here is likely to propagate throughout an entire community. We also know very little about how the public might react to multiple terrorist strikes similar to the London bombings. Do these events accelerate public fear or do people adapt depending on how effectively the attacks are handled? To what degree do threats of terrorist attacks provoke the same response as an actual strike? Finally, it would be helpful to know to what extent people's level of fear during a disaster is influenced from observing the effectiveness of the government's response and the behaviors of others.

4.4.2. Modeling

Many variables likely to influence public reaction (risk signal, media coverage, community intervention) have been modeled. However, other variables such as trust and government response may be needed as well. It would also be helpful to know how these factors change and interact overtime contributing to system feedbacks and delays. Hurricane Katrina and most recently the financial crisis have illustrated with devastating clarity how the effects of a calamity can be made much worse by systems delays. Additionally, understanding the influence of demographic characteristics and worldviews on risk perception may help forecast public reaction within a community. Finally, we have modeled the diffusion of fear, but we need to better understand how fear ripples through different sectors of our society potentially causing widespread impacts on the economy.

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