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The Dynamics of Risk Perception: How Does Perceived Risk Respond to Risk Events?

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This paper examines the relationship between perceived risk and experience. This research addresses the processes by which people learn about risk and choose among real life prospects with associated uncertainties, risks and benefits. By comparing the impact of acute risk events with that of chronic risk events on public perception of risk during and after the events, this research focuses on the learning processes that characterize what kinds of risk events alter the perception of risk. Comparing materialized hazards at existing facilities with the risks associated with potential facilities, this research addresses risk choices among real life prospects. This study uses a classic pre-post quasi-experimental design. Surveys conducted in the Spring of 1992 on perceived and acceptable risk in Odessa and La Porte, Texas were conducted prior to risk events. Respondents from that survey were re-interviewed in the Spring of 1993 after the risk events to form a panel design. This paper analyzes the affect of risk events on perceived risk and the implications of these experiences for public policy concerning technological risk. The empirical results suggest that the social processes that construct and maintain risk in the public eye are at least as important as, if not more important than, the physical and psychological dimensions of risk.

KEY WORDS: Perceived risk; dynamic risk perception; social structural risk perception.

1. INTRODUCTION

People in distant locations are frequently more concerned than people residing near hazardous facilities.[1,2] In examining why people residing near nuclear power plants estimate risk at lower levels than people living further away, Rogers[3] was unable to reject an economic dependence and experience hypothesis. The experience hypothesis posits that relatively low occurrences of risk events are interpreted in the context of daily activity as low risk. While non-neighbors estimate risk at higher levels because the relatively few events of which they are aware are negative. This paper addresses the processes by which people learn about risk and evaluate real life prospects.

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The cognitive psychology literature on risk perception examines risk from a static point of view as if it were a snapshot at a particular time.[4–7] The cultural literature focuses on the underlying values associated with risk perception and thereby considers risk perception from a relatively stable foundation.[8] The social structural perspective on risk perception explicitly incorporates experience into the models that impact perceived and acceptable risk.[9] Unfortunately most of the data used to test these models are cross-sectional. This is not to say that risk perception remains constant. In fact, initially the implicit assumption of risk communication was that risk perception could be changed if people were given additional information.[10,11] Later, the goal of risk communication focused more on the process of incorporating public interests in decisions involving risk.[12] In each of these bodies of literature there are discussions of increased or decreased risk perception, but the fundamental nature of the perspective is static. It is certainly

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reasonable to assume that people can and do learn about risk, otherwise survival of the species would be difficult. Yet there is little scientific research that addresses this process. This paper focuses on the dynamics of risk perception in light of the risk events occurring in two communities, where the salience of these risk events is greatest.

By comparing materialized hazards associated with existing facilities with the risks associated with potential facilities, this research addresses choices among real life risk prospects. Viscusi[13] argues that when risk events occur, the information associated with them is factored into the perception calculus at a fractional value with all other relevant experiences. For neighbors of potentially hazardous facilities, the ongoing experience is mostly non-occurrence data, and directly related to residential tenure. Hence, the information added by an occurrence is quite low and its impact may be difficult to detect. Conversely, in risk events characterized by controversy over a potential facility the denominator of on-going experience is drastically reduced. These groups tend to fit the description of ". . every time I hear about that place it is negative." By comparing risk perception dynamics in these two important and contrasting situations, this study provides a real life examination of the processes that adjust perceived risk to account for risk events when they occur.

This study takes advantage of research conducted in the Spring of 1992 on perceived and acceptable risk in Odessa and La Porte, Texas. These surveys provide data concerning the state of perceived and acceptable risk prior to two dramatically different risk events. By re-interviewing these respondents in the Spring of 1993 a before-after panel is established. This paper analyzes (a) the effect risk events have on perceived risk in 1992 and 1993, (b) the impact of the emergency in Odessa while it was happening, and (c) the effect of residing in the zone of impact on both the perception of risk and the dynamics of the adjustment process.

2. BACKGROUND

Loewenstein and Mather[14] suggest that limited research has been conducted on the trends of perceived risk. Raw trends of social survey data regarding the public's perception of various risks have been reported regarding nuclear war,[15–18] nuclear power,[19,20] and hazardous waste.[21] Even though the examination of trends such as these have become somewhat commonplace, some have questioned the validity of trend analysis.[22] Rogers[9] examines the trend in the perception of the likelihood of nuclear risks to better understand the social structural processes involved in the perception of risk[2] and finds that these underlying positions are at least as important as the temporal trend. The "effect associated with the intervening social/historical event,"[23] (p. 497) has been isolated from the variation associated with the social structure.

Smith and Michaels[24] evaluate a Bayesian framework to explain how people's "reported perception of the health risks posed by nuclear power plants" changed between 1984 and 1986, which is tied loosely to the nuclear power plant accident at Chernobyl (p. 360). Analyzing retrospective risk perceptions, they conclude that "the Bayesian learning model does not appear to provide a clear explanation" of how people interpreted the accident (p. 364). People seem to confound the occurrence of the risk event with the severity of the event. The analysis of panel data regarding residential proximity indicates little change in response to the accident.

Another body of research examines the impact of hazard information or risk communication on perceived risk. Viscusi and O'Conner[25] posit that workers begin jobs with incomplete information about the inherent risks and engage in "an ongoing experimentation process in which they learn about the risks posed by their job and quit once the position becomes sufficiently unattractive" (p. 943). This treats perceived risk, y, as a weighted average of the person's prior risk perception, x, and the risk information communicated, which is formulated as a linear function (i.e., $y = a + bx + e$, where e is a random error term). Because neither the prior perceived risk nor the information content dominate the current perceived risk Viscusi and O'Conner find the results "broadly consistent with a Bayesian learning model" (p. 951).

Liu and Smith[26] examined the public's reaction to a national debate concerning nuclear power in Taiwan via panel data collected in 1988 and 1989. In spite of the disappointing response rate (404/2001 = 20.2%) and regression results that explain less than 5% of the variance, the probabilistic multinomial logit "model indicates that the debate had little effect on the likelihood of attitude changes" (p. 342). In another study, Smith *et al.*[27] examined the incremental effects of radon monitoring and risk information on perceived risk in homes with various levels of radon gas. They found that the

[2] For example, one consistent finding across all analyses indicates that age has a curvilinear effect, with both younger and older adults estimating risk at higher levels than their middle age counterparts. If this trend proves to be stable over time, a natural demographic decline in estimated risk would be anticipated as the baby-boomers reach middle age.

minimal information contained in a fact sheet was related to increased perception of risk, even among households where radon exposures were minimal. Finally, in the case of the high-level nuclear repository, a "well-financed, professionally developed and implemented advertising campaign was forced into premature closure . . ." (p. 501). It did not engender a friendly, receptive attitude, but rather seemed to enhance hostility toward the program. In this sense the campaign was "... a spectacular failure."[28]

An examination of the relationship between concern and severity associated with nine social problems found a relatively high degree of tracking between expressed concern and rate of occurrence, and concern and action.[14] There is no evidence of short-term adaptation in the dynamic risk perception problems examined; however, evidence does support a partial adjustment which "instead of adjusting rapidly, or even overshooting, concern seems to bubble up slowly over time in response to an increase in" perceived risk (p. 173).

This paper examines the public perception of risk associated with two distinct risk events. The chemical plant fire in Odessa is an acute hazard stemming from an existing facility. The siting controversy in La Porte represents a potential facility where the hazard cannot occur because the facility does not yet exist. The siting controversy is a risk event because it sets the conditions under which future hazards materialize. These events are described in greater detail elsewhere.[29]

3. THEORETICAL PERSPECTIVES

Human perception rests on a foundation of experience.[3] Because risks are potential hazards they are by definition perceived; however, they are perceived from a foundation of overall experience that seldom includes experience with the specific hazard. Two theories are particularly relevant to this dynamic process. Learning theory addresses the process by which direct experience leads to learned perception, and prospect theory addresses the incorporation of potential (risk) outcomes into perception.

Learning Theory. An important aspect of how hazard experience accumulates involves learning. Risk knowledge is a special case of learned social behaviors, where "discriminable environmental stimuli (situational cues), drive (as a general arousal state) and reinforcement (primarily as a drive deduction) . . . play central roles in accounting for acquisition and maintenance of observable responses" (p. 109).[31] Several principles of learning theory are applicable to potentially hazardous situations and perception of risk. First, reinforcement plays the dominant role in learning.[31] Behaviors that accomplish their desired goals are reinforced; and reinforced behaviors are more likely to be repeated.[32] Second, the number of repetitions is monotonically related to the rated truth value of uncertain statements.[33–36] Third, the imitation of the behaviors of others is a central form of learning.[37–40] Learning theory clearly focuses on the processes by which experience in a variety of forms is incorporated into personal knowledge.

Prospect Theory. Prospect theory focuses on the structure of decisions by examining the relationship between stimulus and response in the selection of alternatives. Hence for prospect theory to account for change in the selection of alternatives, a shift in the structure of the choice is required.[4] In both low-probability lottery successes and catastrophic events the decision (to gamble or buy insurance) is influenced more by the weighted subjective probability than the objective probability would warrant. Prospect theory argues that "the mere fact that an event is possible may give it a certain credence, of magnitude insufficiently sensitive to the size of the objective probability"[42] (p. 247). While the effects of possibility can be enhanced by the dramatic salience of the event's occurrence, extremely low probability events can also be ignored completely. Kahneman and Tversky[41] conclude that the subjective probability weighting function is not well-behaved at the extremes. This is probably because very rare events fail to provide enough information for people to interpret them in the relative frequency terms required to produce objective probabilities. One tenet of learning theory is that a single rare stimulus is much less likely to lead to learning than an ongoing reinforced stimulus.[31] Hence, the occurrence of rare hazardous events is less likely to increase perceived risk than ongoing controversies that involve multiple exposures to conflicting information, and often require multiple interactions with various stake-holders. For risk events to impact perceived and acceptable risk the value system would have to change

[3] For example, when first encountering Rubin's reversible face-vase illustration of figure-ground segregation, one image usually dominates the other.[30] But once both images are recognized, they are each perceived on subsequent encounters. Hence, personal experience is an important foundation of perception.

[4] This structure is summarized in terms of the value of the alternatives. Generally, prospect theory posits that the value of an alternative, V, is the sum of products over the specified outcomes, x; $V = \Sigma\pi(p_i)\, v(x_i)$; where $\pi(p_i)$ is a subjectively weighted probability of x occurring; and $v(x_i)$ is the utility of x.

for the shift in the structure required by prospect theory. But because value systems are relatively stable such shifts would occur relatively infrequently, and only when compelled to change through experience. Hence, prospect theory suggests a relatively stable perceived and acceptable risk that change only in light of intense (either in terms of frequency or consequences) risk experience.

Another important aspect of how hazard experiences effect perceived and acceptable risk rests with the fundamental difference between risks endowed in existing facilities and risks associated with proposed facilities. The shape of the value function,[5] $v(x)$, produces risk aversion when gains are possible and risk seeking when losses are at stake. Because of the shape of the value function, a small chance of gain or loss is less attractive than the status quo. Hence existing facilities will be preferred to proposed facilities. This endowment emphasizes protecting what people have rather than what may be gained.

Contentious hazard events often require multiple, extended confrontations, meetings and media coverage. In this sense, they are characterized as reinforced stimuli over an extended duration. Because people are more likely to learn from such stimuli, extended contentious hazard events are more likely to impact perceived risk than single hazard events that occur over relatively brief periods. Alternatively, contentious hazard events often involve changing the status quo while increasing the overall risk of an area. Under prospect theory, the additional risks are less attractive than the risk aversion associated with the status quo; consequently, extended risk controversies are more likely to alter perceived risk than isolated hazards associated with existing facilities. Presumably, as hazard consequences become more severe (e.g., in terms of deaths and injuries), or a series of events occur, it is harder to ignore or trivialize the hazard. So, it can be anticipated that as hazards become more severe, or frequent, the distinction between the amount of change in perceived risk is blurred.

4. HYPOTHESES

This research examines two categories of hypotheses. Long-term impacts are examined in terms of the changes in estimated risk before and after the risk events. Tenets of both learning theory and prospect theory suggest the amount of change in risk perception is likely to be greater in La Porte than Odessa. Hence the null hypothesis is that,

1. There are no significant differences between Odessa and La Porte in the amount change in perceived risk before and after risk events.

La Porte is anticipated to create greater change than Odessa unless the event in Odessa was part of an ongoing sequence of events that established a trend or the consequences of the event were quite severe.

Under both learning and prospect theory, the greater locational salience of the risk, the more likely people are to adjust their perceptions on the basis of risk experiences. Hence the null hypothesis is that,

2. People residing in the impact zone change their perceived risk about the same amount and direction as non-residents.

This effect is expected to be greater in Odessa than in La Porte because the locational salience is more clearly defined in Odessa than in La Porte and the acute nature of the risk in Odessa tends to focus the public's attention on the risk events, while the more protracted controversy in La Porte is subject to everyday distractions.

Short-term adjustments are examined in terms of the risk estimates during the events. These hypotheses are similar to the before after hypotheses. Hence, the general null hypothesis is that

3. No significant fluctuations occur in the perceived risks associated with the facility experiencing the risk events during the event.

Because of the intensity of the acute events in Odessa, the amount of change during the event is expected to be greater in Odessa than in the more protracted controversy in La Porte.

Examining the process in terms of those people residing in and out of the impact zone provides additional insight into the nature of the process(es) by which people adjust their risk estimates to accommodate the new information provided by the occurrence of the risk event. The general null hypothesis is that,

4. People in and out of the impact zone change their perceived risk, in similar ways during the risk event.

Once again the magnitude of the fluctuation is anticipated to be larger in Odessa than La Porte.

Because change in perceived risk in Odessa is principally associated with learning, and the change in La Porte is associated with a proposed change in risk prospects, a pattern of change can be anticipated. In Odessa, under learning theory, people residing in the impact zone are likely to increase their perceived risk, while those outside that zone either remain unchanged or decrease

[5] In the region of gains the value function, $v(x)$, monotonically increases, with each unit increase in gain of wealth producing less value than the previous unit; meanwhile in the loss region it decreases monotonically with each unit of decrease having less impact on the overall loss than the previous unit.

their perceived risk. In contrast, under prospect theory, because the zone of impact is socially defined, and the risk events are more commonly shared among all community members, perceived risk will increase both in the zone of potential impact and more broadly in the community as a whole.

5. DATA AND METHODS

Sampling. The initial survey addressed the public perception of the risks associated with two types technological facilities: hazardous waste and energy production.[6] Independent samples represent households in Odessa, and La Porte, Texas. Each sample was a random-digit-dialed sample of working residential blocks in the telephone exchanges associated with the municipalities where a specific facility was located. Each survey addressed the respondent's assessment of the likelihood of accidents and favorability associated with various conditions of operation for the hazardous waste and energy production facilities. Respondents where also asked about the facility in the community that presented the greatest risk to the public, which became the basis for the comparison of risk attitudes associated with a specific facility in 1992.

The 1992 surveys in Odessa and La Porte form the initial base of data reported herein. In these surveys, 70.3% (n = 244) and 63.7% (n = 239) of the respondents completed the items regarding the likelihood of risk in Odessa and La Porte respectively. These respondents were re-interviewed about a year later; and new respondents were added to replace those lost to attrition. In Odessa, a 62.6% response rate[7] resulted in a sample of 283 respondents in Odessa with a sample precision, e (i.e., where $e = 1/)$, of ±5.9%. In La Porte, a 69.6% response rate[8] resulted in a sample of 287 interviews with a sample precision of ±5.9%.

Measurement. The likelihood of risk is examined in the Spring of 1992 and 1993. In Odessa, this is before and after the events of August 20, 1992, where there was no way of knowing which facility would have the fire and resulting emergency. In La Porte, the surveys were conducted during 2 consecutive years near the end of a long contentious public permitting process. Perception of risk was assessed by asking people to rate "the chance that the riskiest facility [i.e., Champion Chemical in Odessa, or "if an incinerator operated by HCS in La Porte was built"] would have a significant release of potentially toxic materials" on a 5-point scale from very unlikely to very likely, with a 50–50 chance midpoint. In addition, respondents were allowed to indicate spontaneously that the event had already occurred or "could not happen" or "never will occur." This Likert scale treats likelihood as a seven point approximation of the probability of occurrence with spontaneous end-points, which is analyzed as if it is interval.[9] Since there is a direct correspondence between a 50–50 chance and a likelihood of 0.5, codes greater than 0.5 may be considered likely (1) while all other responses are considered not likely (0). Operationalizing perceived risk in terms of the likelihood of occurrence taps the catastrophic po-

[6] These data were collected for the Hazard Reduction and Recovery Center by the Public Policy Research Institute at Texas A&M University under a grant from the Coordinating Board for Higher Education in Texas, Advanced Research Program, (hazardous waste) under Grant No. 999903-225, and the Center for Energy and Mineral Resources, Texas A&M University, College Station Texas (energy resources).

[7] Of the 244 initial respondents in Odessa, 127 completed the entire questionnaire in 1993, and 147 completed the risk items on the survey instrument, resulting in a 50.2% or 70.3% completion rate, respectively. To replace respondents lost to attrition, an additional 334 households were randomly selected. Of these 158 telephones were eliminated due to being disconnected, associated with a business or government, no answer on at least five separate occasions, a nonworking telephone number or similar result; of the remaining 176 households, 136 respondents completed interviews in Odessa, yielding a 77.3% response rate among replacements. This results in a 62.6% response rate overall (i.e., completed interviews divided by the number of completed interviews plus refusals = (127 originals + 136 replacements)/(244 + 176)).

[8] Of the 239 initial respondents in La Porte, 146 completed the entire questionnaire in 1993, and 168 completed the risk items on the survey instrument, resulting in a 61.1% or 70.3% completion rate, respectively. To replace those lost to attrition, an additional 262 households were randomly selected. Of these, 120 telephones were eliminated due to being disconnected, associated with a business or government, no answer on at least five separate occasions, a nonworking telephone number or similar result; of the remaining 142 households, 119 respondents completed interviews in La Porte, yielding a 83.8% response rate among replacements. This results in a 69.6% response rate overall (i.e., completed interviews divided by the number of completed interviews plus refusals ≈ (146 + 119)/(239 + 142)).

[9] The categories were arbitrarily assigned equidistant values between 0 and 1 (i.e., 0 is never will occur or could not happen, .17 is very unlikely, .33 is unlikely, .50 is a 50–50 chance, .67 is likely, .83 is very likely and 1.0 is already occurred). Unfortunately, this scale is somewhat insensitive to subtle changes in perceived risk, because changes have to be interpreted in terms of the underlying scale to be meaningful. Changes in underlying category result when the likelihood scale changes more than half the distance between arbitrary points on the likelihood scale (i.e., increases or decreases of approximately .08 points). A binary representation is used so that significant changes in the proportion of respondents estimating risk as greater than a 50–50 chance can be observed and reported. This binary measure also allows the examination of potential biases introduced by the fact that the arbitrary coding of a Likert type ordinal scale technically remains ordinal.

tential of hazardous events, which was among other factors that "strongly influence the ratings of dread and perceived risk associated with technologies, products and activities[43]" (p. 263).

A retrospective tracing methodology was developed to examine the dynamics of risk perception during risk events. Each respondent was asked to trace their activities during the risk event. Three critical junctures were used to characterize the risk dynamics for each individual. First, respondents were asked when they first became aware of the risk events (i.e., the fire at Champion Chemical in Odessa, or HCS's proposal to build an incinerator). In order to help respondents put their responses in the framework of the period, respondents were asked about their activities during that time.[44] Respondents were then asked, "When did you feel the most threatened by the accident [in Odessa or] HCS's proposed facility [in La Porte]? In Odessa, respondents were then asked to rate the likelihood at the time, that "If you chose to do nothing at all you (or someone in your family) would be injured?" and "If you chose to do nothing at all you (or someone in your family) would be killed?" These two questions were used to establish the level of perceived risk when the respondents felt most threatened. Because the risk events in La Porte are substantially and quantitatively different, parallel questions were asked. Respondents in La Porte were then asked to rate the likelihood at the time, that "If the proposed incinerator was built, routine air-borne releases would cause life threatening lung diseases among nearby residents" and "If the proposed incinerator was built, an explosion would expose nearby residents to toxic materials." Finally, in Odessa, respondents were asked, when "did you (and your family) first become aware that the emergency was over?" Since the risk event in La Porte was not over in 1993, respondents were asked, "Since you first became aware of the proposed HCS incinerator in [fill in month and year from awareness question], when did you feel the least threatened?"

Because the time sequence in Odessa was acute in nature and completed at the time of the second interview, a simple step function was used to describe each respondent's perception of risk during the event. This function assumes momentum; specifically that perceived risk, at time t_0, continued into the future until there is reason to believe a change may have occurred, t_i. Subsequently, perceived risk continues until another change is indicated. Hence, the perceived risk in 1992 continued until the respondent became aware of the risk event. The revised perceived risk continued until the event is recognized as over, at which time the perceived risk in 1993 prevails. The same step function is applied in La Porte; however, the situation is complicated by the sequencing of the two surveys with respect to the risk event, which started before the first survey and continued after the second survey. So to make the momentum assumption, the risk inflection points had to be time ordered prior to the step function.

Models and Tests. Previous research has shown that the change between two surveys may be characterized as a linear function,[25] and that this change can be associated with situational attributes.[29] To test the amount of change associated with residing in Odessa or La Porte (hypothesis 1), and residing in the impact zone (hypothesis 2) on the adjustment process, the risk estimates are

$$y = a + b_1x + b_2\zeta + b_3\zeta x + b_4\Omega + b_5\Omega x + b_6\zeta\Omega + b_7\zeta\Omega x + e \qquad (1)$$

where ζ equals one if the respondent lives in the impact zone, else b equals 0, and Ω equals 1 if the respondent lives in Odessa, else Ω equals 0. The intercept, a, is modified by b_2, b_4, and b_6 for residing in the impact zone, Odessa, and both the impact zone and Odessa, respectively. The amount of change, b_1, is modified b_3, b_5, and b_7 associated with these three situational attributes, respectively, and e is a random error term.

A fourth-order polynomial regression is fit to each curve, to represent the oscillation during the event (hypothesis 3). As long as the estimation is done within the time period being examined the general model is expressed as,

$$y = a + b_1t + b_2t^2 + b_3t^3 + b_4t^4 + e \qquad (2)$$

where y is the estimated risk at time t, a is the intercept, t^i are the first-, second-, third-, and fourth-order temporal measures, b_i represent the regression effects of the respective time measures and e is a random error term. The intercept, a, represents the average risk estimation at the beginning of the period. The effect, b_1, associated with time, t, captures the overall slope of the curve. The effect, b_2, associated with t^2, reflects the most significant "dip or peak" in the risk estimation during the period. The third and higher-order effects (e.g., b_3, b_4, . . .) reflect subsequent oscillations during the event in descending order of magnitude—a change in the slope, or an inflection point.

Fitting independent models to each curve may describe each process well, but fails to test whether different processes are being used by people in or out of the evacuation zone (hypothesis 4). One additional term for each general term in Eq. (4), is required to represent each significant effect of the model. Thus to test for significant differences, Eq. (4) becomes

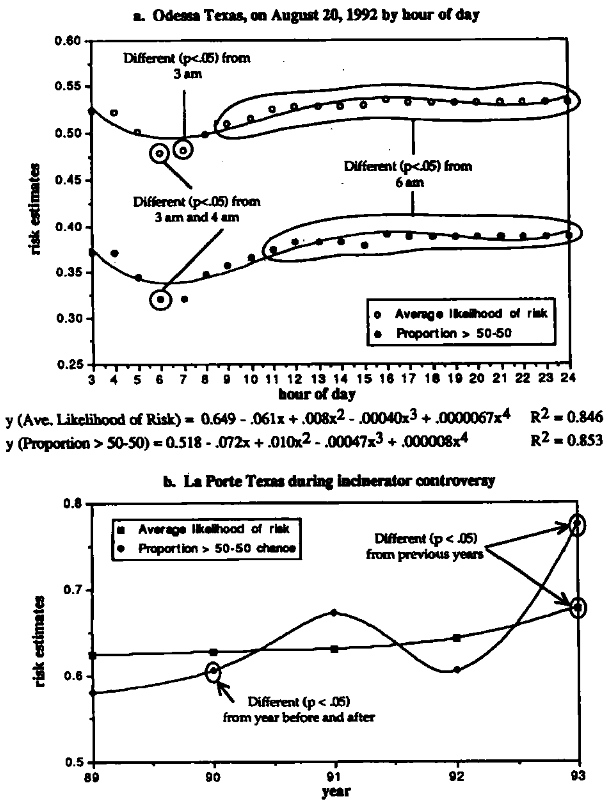

Fig. 1. Average likelihood and proportion above 50–50 chance.

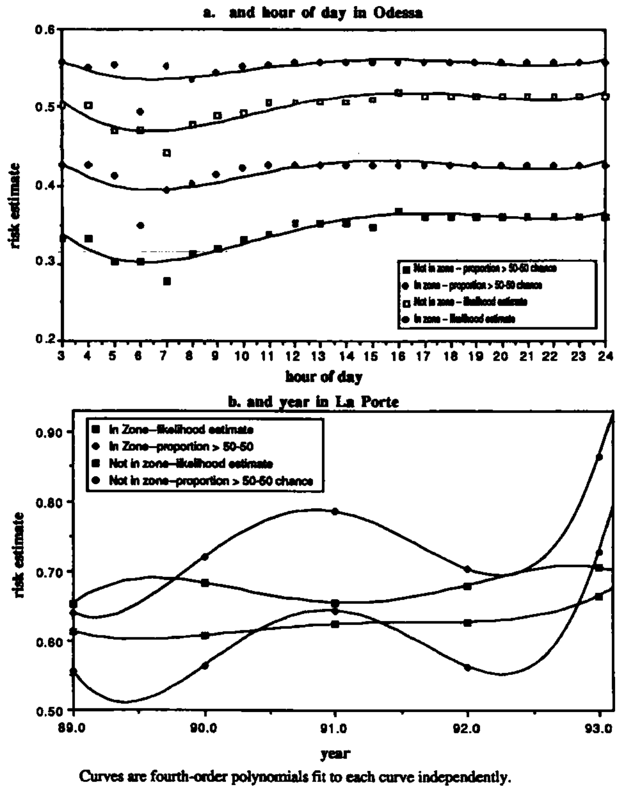

Fig. 2. Risk likelihood (r) and proportion above 50–50 chance (p) by zone of impact.

$$y = a + b_1 t + b_2 t^2 + b_3 t^3 + b_4 t^4 + b_5 \zeta + b_6 \zeta t + b_7 \zeta t^2 + b_8 \zeta t^3 + b_9 \zeta t^4 + e \quad (3)$$

where y, a, t^i and b_i, are defined as before when i one to four, but when i is greater than four they represent an adjustment to the general model to account for being located in the evacuation zone. If the processes of risk perception were independent of being in the evacuation zone, then all b_i effects would have significant impacts on the risk estimate; however, visual inspection of Fig. 2 reveals similarities in the patterns associated with being in and out of the evacuation zone.

6. RESULTS

While most people reported that they had changed their risk perception during the study period, about three in ten did not change their risk estimates.[29] Neither of the measures of perceived risk changed in Odessa, yet they increased significantly in La Porte.[29]

The simplified general linear models for each risk estimate before and after the risk events are presented elsewhere.[29] Most importantly, three terms in Eq. (3) are found to have no significant impact on the current estimates of risk, given the prior estimates: (1) saliency in terms of living in the impact zone, (2) residing in Odessa and being exposed to the events of August 20, 1992, and (3) living in the impact zone in Odessa. Hence the expectation that people in Odessa would learn, or adjust their risk estimates to account for the information associated with the emergency was not supported. Moreover, people residing in the zone in either city, were expected to adjust their risk estimates most, but this is not supported by the test. Finally, people residing in the evacuation zone in Odessa failed to learn or adjust their estimates of risk in significantly different ways from those people outside the evacuation zone.

During Risk Events. A consistent temporal referent is required to test the significance of the oscillations during the risk event (hypothesis 4). In both Odessa and La Porte the data were coded at whatever level of detail the respondent could recall, so it was possible to re-examine the temporal trend by the most universally recalled level. In Odessa, the fire occurred over the course of a day, and hour was the most likely level of temporal detail recalled resulting in the curves in Fig. 1a. In La Porte the controversy occurred over the course of years, people were most able to recall the year in which things occurred, resulting in the curves presented in Fig. 1b. Relatively few people reported becoming aware of the events in La Porte prior to 1989, so all estimates prior to 1989 are included in the 1989 averages.

Figure 1a presents the hourly averages of the risk estimates in Odessa. Difference of means tests were performed on each pair of each risk estimate (i.e., 210 *t*-tests in all). The average risk estimates before 5 a.m. and after 9 a.m. on were found to be significantly different from the hourly average at 6 a.m. In addition, the average proportion estimating the risk as greater than a 50–50 chance were found to be significantly different before 5 a.m. and after 11 a.m. Meanwhile, the oscillation in the proportion estimating the risk above a 50–50 chance begins the day at around 37% and declines about 5 percentage points to around 32% by 6 a.m.; the proportion estimating the likelihood of risk then increases to around 38% by noon, where it remains for the rest of the day.

Figure 1b presents the trend of estimated likelihood of risk and the proportion estimating the likelihood as greater than a 50–50 chance in La Porte by year. Only the 1993 estimates are significantly higher than the estimates associated with the other years of the controversy. In addition, the proportion estimating the likelihood as greater than a 50–50 chance is greater than the previous year and less than the following year. Unfortunately, the limited number of temporally distinguishable periods makes further analysis unwarranted.

A fourth order polynomial was fit to both the estimated likelihood and the proportion estimating the likelihood as greater than a 50–50 chance in Odessa (Fig. 1). The similarity between the two curves is readily apparent. The first order term of both polynomials indicates a positive overall trend, while the second order term seems to capture the first change of direction at 6 a.m. and 7 a.m. The third order term reflects a leveling off after the steady increase in perceived likelihood of risk during the morning hours of the emergency. The fourth order terms seems to reflect a slight adjustment during the evening hours following the fire at Champion Chemical. Given the polynomial character of the curvilinear model, the predicted values associated with hours before or after the reported period are suspect.

It is reasonable to ask why estimated likelihood of risk declines at the height of the emergency. Recall that the estimated likelihood of risk during the emergency included the consequences of death and injury, while the estimates before and after the fire included only exposure. The decline could be associated with this measurement anomaly, or it may reflect a decline among people living in areas that were not threatened by the fire and resulting plume. This is explored further in Fig. 2 by refitting a fourth order polynomial among people in the evacuation zone and those living outside the zone, allowing a descriptive comparison of the effects among these important groups. First, the patterns generally oscillate over the time period; and both groups and risk estimates tend to fluctuate together. Second, people in the zone generally estimate risk (i.e., both likelihood of risk and proportion above the 50–50 level) at higher levels than those people not in the evacuation zone. Third, the differences between estimates for people in and out of the evacuation zone seem to be greatest during the height of the evacuation, and decline over the course of the day. Finally, the decline during the early hours of the emergency (i.e., as people become aware of the emergency) seems to be deeper among those people outside the evacuation zone. Hence the decline would be consistent with the explanation that the decline is associated with the measurement anomaly.

Table I presents the regression estimates for simplified models of the time series for those in and out of the evacuation zone. The intercept is 10–20% higher among people in the evacuation zone than among those people residing outside the zone, depending on which risk estimate is used. Since no evacuation zone existed prior to the event, it is difficult to imagine that people in the zone estimated risk differently. But inasmuch as these data are retrospective in nature, constructed to reflect the processes during the emergency, the significantly different intercept is accounted for by the retrospective nature of the data. The ceiling effect is 0.5–1% smaller for those in the zone compared to other residents. The slightly reduced ceiling effect reflects a gradual reduction in the difference between those people in the zone and those residing elsewhere over the course of the event. No significant differences were found for (a) the declining overall slope, (b) the significant dip in risk estimates at the height of the event (i.e., 6 a.m. to 7 a.m.), and (c) the small inflection in the early evening hours between people residing in or out of the zone. Overall, people in the evacuation zone adjusted their risk estimates in similar ways to those people outside the evacuation zone over the course of the emergency.

7. DISCUSSION

It is difficult to imagine a risk perception that remains constant in the face of risk events such as those experienced in Odessa and La Porte. Postulating a static risk perception would involve describing mechanisms by which people continue to hold-fast to views of risk in

Table I. Time series regression for average risk likelihood estimates and proportion estimating risk as greater than a 50–50 chance by emergency zone

	Risk likelihood			Proportion > 50–50 chance		
	b	β	*t*	*b*	β	*t*
Hour	−0.055	−11.396	−4.831	−0.066	−9.585	−5.429
Hour²	0.007	41.443	4.748	0.009	35.246	5.395
Hour³	−3.57[a]	−49.210	−4.403	−4.38[a]	−41.944	−5.015
Hour⁴	6.05[b]	19.470	4.054	7.44[b]	16.613	4.622
In zone	0.060	0.983	11.444	0.091	1.036	16.118
In zone*hour²	−4.04[c]	−0.221	−2.192	−6.32[c]	−0.240	−3.174
Constant	0.611	0.000	22.171	0.469	0.000	15.789
R^2		0.896			0.942	
Adj. R^2		0.879			0.932	
Model probability		0.000			0.000	

[a] Hour³ coefficients (*b*) are reported in scientific notation ($b \times 10^{-4}$).
[b] Hour⁴ coefficients (*b*) are reported in scientific notation ($b \times 10^{-6}$).
[c] In zone* hour² coefficients (*b*) are reported in scientific notation ($b \times 10^{-5}$).

the face of new and even contradictory information, particularly when risk events with potentially life threatening consequences are considered. The adjustments identified herein are smaller and less patterned than was anticipated. Like previous research, the results herein are broadly consistent with a Bayesian learning model,[26,25] and a slow inertia model of adjustments to perceived risk.[14] The results of this study, particularly in Odessa, are consistent with slowly evolving risk adjustment to the experience of the situation, even in the face of dramatic acute events.

These results suggest that the public, like workers on the job,[25] may reside in areas with less than perfect information regarding the potential hazards faced. This information is continually updated with hazard occurrence data, which for low-probability events is overwhelmingly non-occurrence data. When a risk event does occur, this information is placed in a context of all the risk data on occurrence.[10] In essence, resident perceptions of hazardous facilities reflect both the impact of risk events, as well as the affects of non-occurrence. For relatively low-probability events the non-occurrence information simply swamps the occurrence data, making any adjustment nearly unobservable.

Contrast this with the situation of a proposed facility, particularly one embroiled in controversy, such as the HCS incinerator in La Porte. Residents have no cumulative experience with proposed facilities. When they become aware of the controversy, they begin to accumulate risk events that focus on the possibility of unwanted events. It is not hard to imagine that these data accumulate in the sense that nearly every time a resident hears about the proposed facility it is negative. But in this case, no matter how many risk events the person experiences, there are far fewer "non-occurrence" experiences to counterbalance them. For example, if a resident accumulates 100 risk experiences (e.g., rallies attended, articles read, etc.) with a potential facility and just a quarter of them are negative, the hazard occurrence information is weighted by a factor of one in four (25/100 = .25). By comparison, this is many times greater than for the existing facility, which accumulates ongoing non-occurrence experience. In most controversies the ratio would be much higher, yielding an increased perceived risk. Certainly the results in La Porte, which were characterized by a siting controversy, show greater impact on perceived risk in that community than in Odessa, where an acute hazard occurred.

Lawless[45] found that one mechanism that leads to regulation involved trigger events that sensitize the media and the public to the potential for harm.[11] Risk events often triggered initial public concern and media attention

[10] For example, a resident living in Odessa (within the evacuation zone) for just one year at the time of the fire had accumulated 5840 waking-hours of non-occurrence data. The event lasted only 8–10 hours, even for the most isolated households. Hence, the hazard occurrence information is weighted by a factor of less than two per thousand (i.e., 10 hours/5850 hours = .0017).

[11] Over half of the 45 technologies examined were employed "with less than adequate responsibility by its users," (p. 490) and most of these occurred after initial concerns were raised. In nearly two-thirds of the cases new research concerning the technology "played an important or central role in the discovery that a threat existed" (p. 491).

which seldom led directly to threat reduction. Rather, "public concern very often led, after a time, to a hearing by a government agency . . . and sufficient publicity resulted from this platform of expression that change was initiated" (p. 508).

While the acute risk events in Odessa would certainly be considered candidate trigger events with definite potential for change in the political or regulatory framework, this can only happen if public concern is altered. Because the support for change in perceived risk associated with the acute events of August 20, 1992 is rather limited, risk events such as these may not be triggers for regulatory change. Conversely, the incinerator controversy in La Porte not only created greater change in public concern but also required resolution in the courts. Consistent with Lawless,[45] early concerns provide insufficient impetus for regulatory change, but concerns that lead to a public platform are more likely to lead to an ultimate resolution.

What leads some situations to public concern, controversy and resolution while other risk events fail to trigger public concern in an appreciable manner? Events that become part of an ongoing pattern are more likely to lead to enhanced public concern.[45] In Odessa, not only was there no pattern of accident or hazard for the fire to fit into, but being ignited by lightning allowed the public to think of the event as an "act of God" rather than a "technological failure." In addition, even though the fire in Odessa resulted in a large evacuation, there were no deaths and only limited injuries. This may signal an adequate overall hazard management in terms of emergency preparedness and response. And finally, the evacuation in Odessa can be interpreted as leaving the public in control—able to make decisions that bear directly on their own safety (i.e., to evacuate or not). In La Porte, people are unable to intervene routinely in the generation of stack emissions. These occur on an ongoing basis, over which they have little control, and their only recourse is to remove themselves permanently from the "threatened area." Even if they are able to move, the overall value of the real estate declines due to market pressures created by an increase in supply in that neighborhood. Hence proposed chronic hazards such as incinerators engender another motivation for increased public concern. In this very stark sense, both the actual hazard as defined empirically, and the psychological risk as reflected in an individual's mind are less important than the socially constructed risk that develops in the context of a social system that reinforces its development and existence whether the hazard exists or not.

One compelling approach to regulating risk involves trial and error.[46] The trial and error approach searches for safety by allowing trials or experience to accumulate so that society can learn from the errors.[12] Wildavsky[46] argues that incremental errors "are welcomed so long as they are small and diverse" and not cumulative or catastrophic, because this is how people and societies learn about hazards (p. 26). The trial and error strategy for risk management depends on learning. In fact a convincing argument could be made that learning is the cornerstone of the trial and error risk management strategy.

But what happens to this strategy if people do not learn when hazards occur, as suggested by the events examined herein? It could be argued that exactly appropriate learning took place, inasmuch as there were no deaths and limited injuries associated with the Odessa fire. It could also be argued that one event does not form a pattern of either high risk or poor risk management. The natural research questions that cannot be addressed herein are how many events form a pattern that can lead to a regulatory transformation platform? How serious do they need to be to engender change in risk policy? Conversely, how effective can trial and error be as a risk management strategy, when as these findings suggest, public concerns are raised by controversies about potential risks of proposed facilities? This actually amounts to a kind of error without trial, rather than Wildavsky's nemesis, trial without error. Public concern is created by the mere proposal of a facility. On the surface this seems to be simply trial without error, but the results herein suggest that people are learning from these risk events, so the experience is accumulating without trial, but it is not an actuarial experience. Hence, the implications from this study, while preliminary, seem to run exactly counter to the effective use of a trial and error risk management strategy, particularly in cases where Wildavsky[46] seems to be suggesting a larger role for trial and error: diverse, dispersed, moderate to low risk hazards.

8. CONCLUSIONS

Perceived risk was adjusted in La Porte during the period, but was not significantly altered in Odessa.[29] The amount of change was significantly different in the two comparison communities. In fact the results herein indicate that for all potential values of risk (i.e., between

[12] This treats risk regulation much like a child learning not to touch a hot burner. The pain of the burn acts as a natural feedback system advising the child not to touch the burner in the future. Moreover, as long as the trial is not life-threatening, the child learns to avoid this risk in the future.

zero and one), the best estimate in Odessa is essentially the 1992 risk estimate, but in La Porte the regression estimate is greater than the 1992 perceived risk, except for extremely large values. Even though it can be argued that these results are consistent with a Bayesian learning model, there are no significant model adjustments associated with being in the zone of impact. This indicates that learning is selective, but that the selection criteria are not particularly related to salience.

While the results herein are broadly consistent with a both a Bayesian learning model and prospect theory, the limited change in perceived risk observed in Odessa limits the support for learning model. Meanwhile in La Porte, the changes or adjustments were not widely generalized to other types of risks either currently present in the community or hypothetical risks posed for the community.[29] While the empirical evidence herein is far from conclusive, it suggests that the social processes involved in the construction and maintenance of risk perception are more important than either the empirically grounded (i.e., in the actual occurrence of the risk event) risk, or the purely psychologically grounded perceived risk. Neither learning theory nor prospect theory alone (or jointly) provide an adequate explanation for the response patterns observed; however, the results seem to be consistent with a social construction of risk that includes both the likelihood and severity of potential risks and hazards, and the degree to which people are personally affected by the hazard's occurrence or its saliency.

Even though there were no significant differences before and after the chemical fire in Odessa, the fluctuations on the day of the emergency were significant. Moreover, the adjustments made during the emergency seem to oscillate over the duration of the accident and quickly stabilize at levels near the prior estimates when the emergency period ends. The functions used to describe the fluctuations for people residing within the impact zone are surprisingly similar to those used for people not residing in the impact zone. There are two significant differences: (1) the initial starting point is higher among those within the impact zone than for people outside the impact zone, and (2) those not in the impact zone continue to increase their risk estimates after the emergency is over, which quickly reduces the difference between groups. Because the zone of impact was not understood prior to the events of August 20, 1992, the significantly different starting point is best attributed to the differential recall associated with retrospective data collection. Meanwhile the overall parallel nature of the functions indicates a strikingly similar overall adjustment process. People in the zone of impact adjusted their risk estimates with a process that is similar to that used by people outside the impact zone. But the relatively quick close of these differences seems to indicate that, whatever processes were engaged during the emergency, any differences are quickly forgotten.

Although these results are broadly consistent with a Bayesian learning model, learning theory alone does not provide a sufficient explanation for the resulting pattern. First, the major tenets of learning are not confirmed in a predictable manner. Second, there is a strong component of inertia holding perceived risk at stable preconceived levels. Finally, when changes in perceived risk do occur in Odessa during the emergency, they quickly revert to previous levels. The results are also broadly consistent with prospect theory in that La Porte residents were more likely to change their perception of risk than Odessa residents. Yet in La Porte, the prospect of a proposed chronic hazard seems to form a platform for continued exposure to and accumulation of risk events that lead to increased concern. Hence, neither learning theory nor prospect theory alone fully account for the pattern of results reported herein. The results seem to suggest that perceived risk is socially constructed. Perceived risk is more likely to adjust dynamically to the experience of risk events when the risk events are consistent with an existing social context. This indicates that risk events are interpreted through social processes which construct, reconstruct and maintain perceived risk through time. For example, social interaction with family, friends and acquaintances before, during and after risk events shape their meaning. Because platforms for public participation tend to be established when events are interpreted negatively (e.g., the controversy arises), an active role in disseminating information concerning safety is required to balance the experience associated with negative publicity which is often the focus of media attention.

The current paper reflects public risk estimates associated with concrete risk experience and real life risk prospects in two communities—a topic that has received limited attention, to date. This study is important even though it is exploratory. First, it is not definitive because it represents the experience of only two communities. Second, the samples are representative of the communities involved, but present the most important limitation of this research. The sheer lack of cases forecloses the possibility of exploring potentially fruitful investigations into the nature of the process, the demographic profile of people selecting different learning paths and the social processes involved in the variations of adjustment to risk events. Third, these results can be criticized for being predominately retrospective. This is a fundamental limitation of not controlling the risk events, but that is the nature of the phenomena under study. Even if large empirical panels could be established for communities with potentially hazardous facilities, by not knowing which facility will have significant hazard events occur in the future, the researcher is unable to establish effective before-after empirical data. Fourth, because this study chooses to represent actual risks, in real communities a "broad-net" approach is used to increase the likelihood of forming a panel. People are asked very limited information about many risks, rather than a lot about a few risks. While this is a reasonable exploratory approach, it also has its drawbacks. Perhaps the most important among these is the inability to fully represent perceived risk in a multidimensional way. In spite of these distinct limitations, this study represents the beginning of an important area of research that addresses changes in perceived risk associated with actual risk events in existing communities.

Four types of future research on the dynamic aspects of perceived risk are envisioned: (1) large-scale comparative retrospective surveys, (2) panel surveys in communities likely to experience hazards, (3) experimental studies focused on change in perceived risk, and (4) focused panel studies in communities receiving specific risk information. Large-scale retrospective studies in communities where risk events have occurred allow the examination of a specific single risk in-depth, examine its dynamics via a tracing method, and compare the dynamics with communities without direct experience with the risk event. Panel studies in communities likely to experience risk events can achieve a comparative before–after research design for relative risks which are salient in the communities. Experimental studies can control the events surrounding hazard events, but must simulate the events themselves. Panel surveys focused on communities receiving risk information allow the greatest amount of control in a field setting, but these studies need to focus both on the risk communication processes and the dynamics of perceived risk. Risk analysts know remarkably little about how perceived risk changes in the face of risk events. This paper represents one of the first steps toward a better understanding of the processes by which people adjust their perceptions of risk. This important area of risk study requires much greater attention in the future.

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