Perception of Risk Posed by Extreme Events

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1.0 Introduction

Extreme events, by definition, cause much harm to people, property, and the natural world. Sometimes they result from the vagaries of nature, as in the case of flood, earthquake, or storm, and thus are truly the outcomes of "games against nature." In other cases they follow technological failure or unintentional human error, as in the case of Chernobyl or Bhopal, putting them also into the category of risks that are predictable only probabilistically. More recently we have witnessed another form of extreme hazard, resulting from terrorism. One of us has termed this "a new species of trouble" (Slovic, in press), since it involves an intelligent and motivated opponent, putting the situations that give rise to these types of extreme events into the domain of economic game theory. The purpose of this brief review is to examine what existing research can tell us about the perception of risk associated with these extreme events. We will also point out issues that remain in need of exploration.

During the past quarter-century, researchers have been studying risk intensively and from many perspectives. The field of risk analysis has grown rapidly, focusing on issues of risk assessment and risk management (see Figure 1). The former involves the identification, quantification, and characterization of threats to human health and the environment. The latter, risk management, centers around processes of communication, mitigation, and decision making. Management of extreme events will undoubtedly look to risk assessment for guidance. But risk analysis is a political enterprise as well as a scientific one, and public perception of risk also plays a role in risk analysis, bringing issues of values, process, power, and trust into the picture (Slovic, 1999).

Perceptions of risk play a prominent role in the decisions people make, in the sense that differences in risk perception lie at the heart of disagreements about the best course of action between technical experts and members of the general public (Slovic, 1987), men vs. women

(Finucane, Mertz, Flynn, & Satterfield, 2000; Flynn, Slovic, & Mertz, 1994; Weber, Blais, & Betz, 2002), and people from different cultures (Weber & Hsee, 1998, 1999). Both individual and group differences in preference for risky decision alternatives and situational differences in risk preference have been shown to be associated with differences in perceptions of the relative risk of choice options, rather than with differences in attitude towards (perceived) risk, i.e., a tendency to approach or to avoid options perceived as riskier (Weber & Milliman, 1997; Weber, 2001a). Perceptions and misperceptions of risk, both by members of the public and by public officials, also appear to play a large role in the current examination of American preparedness to deal with the threat of terrorism. Thus risk perception is the focus of this white paper.

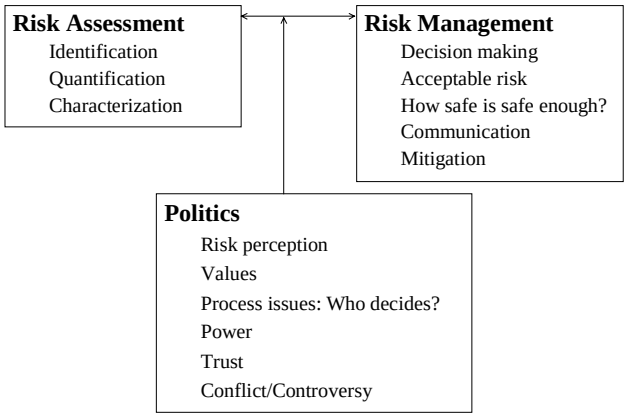

Figure 1. Components of risk analysis.

2.0 What is Risk?

Before reviewing research on public perceptions of risk, it is instructive to examine the very nature of the risk concept itself. It contains elements of subjectivity that provide insight into the complexities of public perceptions. There are clearly multiple conceptions of risk. In fact, a paragraph written by an expert may use the word several times, each time with a different meaning not acknowledged by the writer. The most common uses are:

- Risk as a hazard. Example: “Which risks should we rank?”
- Risk as probability. Example: “What is the risk of getting AIDS from an infected needle?”
- Risk as consequence. Example: “What is the risk of letting your parking meter expire” (answer: “Getting a ticket”)
- Risk as potential adversity or threat. Example: “How great is the risk of riding a motorcycle?”

The fact that the word “risk” has so many different meanings often causes problems in communication. Regardless of the definition, however, the probabilities and consequences of adverse events, and hence the “risks,” are typically assumed to be objectively quantified by risk assessment.

Much social science analysis rejects this notion, arguing instead that such objective characterization of the distribution of possible outcomes is incomplete at best and misleading at worst. These approaches focus instead on the effects that risky outcome distributions have on the people who experience them. In this tradition, risk is seen as inherently subjective (Krimsky & Golding, 1992; Pidgeon, Hood, Jones, Turner, & Gibson, 1992; Slovic, 1992; Weber, 2001b; Wynne, 1992). It does not exist “out there,” independent of our minds and cultures, waiting to be measured. Instead, *risk* is seen as a concept that human beings have invented to help them understand and cope with the dangers and uncertainties of life. Although these dangers are real, there is no such thing as “real risk” or “objective risk.” The nuclear engineer’s probabilistic risk estimate for a nuclear accident or the toxicologist’s quantitative estimate of a chemical’s carcinogenic risk are both based on theoretical models, whose structure is subjective and assumption-laden, and whose inputs are dependent on judgment. Nonscientists have their own models, assumptions, and subjective assessment techniques (intuitive risk assessments), which are sometimes very different from the scientists’ models (See, e.g., Kraus, Malmfors, & Slovic, 1992; Morgan, Fischhoff, Bostrom, & Atman, 2002). Models of (subjective) risk perception, described in

Section 3.0 help us understand the different ways in which the existence of particular uncertainties in outcomes are processed and transformed into a subjective perception that then guides behavior. Section 4.0 on *Risk as Feelings* addresses a converging body of evidence that suggests that those subjective transformations and processes are not purely cognitive, but that affective reactions play a central role.

One way in which subjectivity permeates risk assessments is in the dependence of such assessments on judgments at every stage of the process, from the initial structuring of a risk problem to deciding which endpoints or consequences to include in the analysis, identifying and estimating exposures, choosing dose-response relationships, and so on.

For example, even the apparently simple task of choosing a risk measure for a well-defined endpoint such as human fatalities is surprisingly complex and judgmental. Table 1 shows a few of the many different ways that fatality risks associated with a chemical manufacturing plant can be measured. How should we decide which measure to use when planning a risk assessment, recognizing that the choice is likely to make a big difference in how the risk is perceived and evaluated?

Table 1. Some Ways of Expressing Fatality Risks

- Deaths per million people in the population
- Deaths per million people within **x** miles of the source of exposure
- Deaths per unit of concentration
- Deaths per facility
- Deaths per ton of air toxin released
- Deaths per ton of air toxin absorbed by people
- Deaths per ton of chemical produced
- Deaths per million dollars of product produced
- Loss of life expectancy associated with exposure to the hazard

Each way of summarizing deaths embodies its own set of values (National Research Council. Committee on Risk Characterization, 1996). For example, "reduction in life expectancy" treats deaths of young people as more important than deaths of older people, who have less life expectancy to lose. Simply counting fatalities treats deaths of the old and young as equivalent; it also treats as equivalent deaths that come immediately after mishaps and deaths that follow painful and debilitating disease or long periods during which many who will not suffer disease live in daily fear of that outcome. Using "number of deaths" as the summary indicator of risk makes no distinction between deaths of people who engage in an activity by choice and have been benefiting from that activity and deaths of people who are exposed to a hazard involuntarily and get no benefit from it. One can easily imagine a range of arguments to justify different kinds of unequal weightings for different kinds of deaths, but to arrive at any selection requires a value judgment concerning which deaths one considers most undesirable. To treat the deaths as equal also involves a value judgment.

3.0 Studying Risk Perceptions

Just as the physical, chemical, and biological processes that contribute to risk can be studied scientifically, so can the processes affecting risk perceptions. Weber (2001b) reviews three approaches by which risk perception has been studied: the axiomatic measurement paradigm, the socio-cultural paradigm, and the psychometric paradigm. Studies within the axiomatic measurement paradigm have focused on the way in which people subjectively transform objective risk information, i.e., possible consequences of risky choice options such as mortality rates or financial losses and their likelihood of occurrence, in ways that reflect the impact that these events have on their lives. Studies within the socio-cultural paradigm have examined the effect of group- and culture-level variables on risk perception. Research within the psychometric paradigm has identified people's emotional reactions to risky situations that affect

judgments of the riskiness of physical, environmental, and material risks in ways that go beyond their objective consequences. Since the last paradigm is most germane to the purposes of this paper, we discuss it in more detail.

3.1 The Psychometric Paradigm

One broad strategy for studying perceived risk is to develop a taxonomy for hazards that can be used to understand and predict responses to their risks. A taxonomic scheme might explain, for example, people's extreme aversion to some hazards, their indifference to others, and the discrepancies between these reactions and experts' opinions. The most common approach to this goal has employed the psychometric paradigm (Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Slovic, Fischhoff, & Lichtenstein, 1984), which uses psychophysical scaling and multivariate analysis techniques to produce quantitative representations of risk attitudes and perceptions. Within the psychometric paradigm, people make quantitative judgments about the current and desired riskiness of diverse hazards and the desired level of regulation of each. These judgments are then related to judgments about other properties, such as (i) the hazard's status on characteristics that have been hypothesized to account for risk perceptions and attitudes (for example, voluntariness, dread, knowledge, controllability), (ii) the benefits that each hazard provides to society, (iii) the number of deaths caused by the hazard in an average year, (iv) the number of deaths caused by the hazard in a disastrous year, and (v) the seriousness of each death from a particular hazard relative to a death due to other causes.

Numerous studies carried out within the psychometric paradigm have shown that perceived risk is quantifiable and predictable. Psychometric techniques seem well suited for identifying similarities and differences among groups with regard to risk perceptions and attitudes (see Table 3). They have also shown that the concept "risk" means different

Table 3. Ordering of perceived risks for 30 activities and technologies. The ordering is based on the geometric mean risk ratings within each group. Rank 1 represents the most risky activity or technology.

Activity or Technology	League of Women Voters	Active College Students	Club Members	Experts
Nuclear power	1	1	8	20
Motor vehicles	2	5	3	1
Handguns	3	2	1	4
Smoking	4	3	4	2
Motorcycles	5	6	2	6
Alcoholic Beverages	6	7	5	3
General (private) aviation	7	15	11	12
Police work	8	8	7	17
Pesticides	9	4	15	8
Surgery	10	11	9	5
Fire fighting	11	10	6	18
Large construction	12	14	13	13
Hunting	13	18	10	23
Spray cans	14	13	23	26
Mountain climbing	15	22	12	29
Bicycles	16	24	14	15
Commercial aviation	17	16	18	16
Electric power (non-nuclear)	18	19	19	9
Swimming	19	30	17	10
Contraceptives	20	9	22	11
Skiing	21	25	16	30
X-rays	22	17	24	7
High school and college football	23	26	21	27
Railroads	24	23	20	19
Food preservatives	25	12	28	14
Food coloring	26	20	30	21
Power mowers	27	28	25	28
Prescription antibiotics	28	21	26	24
Home appliances	29	27	27	22
Vaccinations	30	29	29	25

things to different people. When experts judge risk, their responses correlate highly with technical estimates of annual fatalities. Lay people can assess annual fatalities if they are asked to (and produce estimates somewhat like the technical estimates). However, their judgments of risk are related more to other hazard characteristics (for example, catastrophic potential threat to future

generations) and, as a result, tend to differ from their own (and experts') estimates of annual fatalities.

Various models have been advanced to represent the relationships between perceptions, behavior, and these qualitative characteristics of hazards. The picture that emerges from this work is both orderly and complex.

Psychometric studies have demonstrated that every hazard has a unique pattern of qualities that appears to be related to its perceived risk. Figure 2 shows the mean profiles across nine characteristic qualities of risk that emerged for nuclear power and medical x-rays in an early study (Fischhoff et al., 1978). Nuclear power was judged to have much higher risk than x-rays and to need much greater reduction in risk before it would become "safe enough." As the figure illustrates, nuclear power also had a much more negative profile across the various risk characteristics.

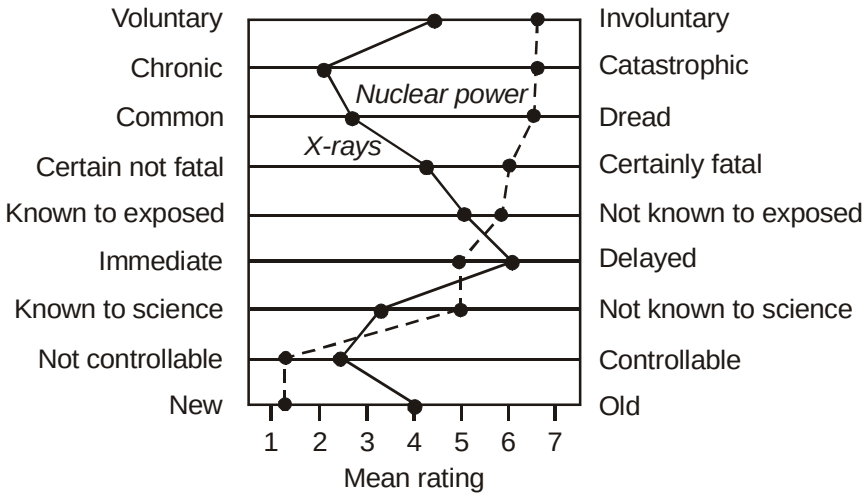

Figure 2. Qualitative characteristics of perceived risk for nuclear power and X-rays across nine risk characteristics.

Many of the qualitative risk characteristics that make up a hazard's profile tend to be highly correlated with each other, across a wide range of hazards. For example, hazards rated as "voluntary" tend also to be rated as "controllable" and "well-known;" hazards that appeared to threaten future generations tend also to be seen as having catastrophic potential, and so on.

Investigation of these interrelationships by means of factor analysis has indicated that the broader domain of characteristics can be condensed to a small set of higher-order characteristics or factors.

The factor space presented in Figure 3 has been replicated across groups of lay people and experts judging large and diverse sets of hazards. Factor 1, labeled "dread risk," is defined at its high (right hand) end of perceived lack of control, dread, catastrophic potential, fatal consequences, and the inequitable distribution of risks and benefits. Nuclear weapons and nuclear power score highest on the characteristics that make up this factor. Factor 2, labeled "unknown risk," is defined at its high end by hazards judged to be unobservable, unknown, new, and delayed in their manifestation of harm. Chemical and DNA technologies score particularly high on this factor. A third factor, reflecting the number of people exposed to the risk, has been obtained in several studies.

Although we do not know of recent studies of risk perception regarding the terrorism of September 11 and the subsequent anthrax attacks, these incidents would most certainly fall in the extreme upper-right quadrant of Figure 3.

Research has shown that laypeople's risk perceptions and attitudes are closely related to the position of a hazard within the factor space. Most important is the factor "Dread Risk." The higher a hazard's score on this factor (i.e., the further to the right it appears in the space), the higher its perceived risk, the more people want to see its current risks reduced, and the more they want to see strict regulation employed to achieve the desired reduction in risk. In contrast, experts' perceptions of risk are not closely related to any of the various risk characteristics or factors derived from these characteristics. Instead, experts appear to see riskiness as synonymous with expected annual mortality (Slovic et al., 1979). Many conflicts between experts and laypeople regarding the acceptability of particular risks are the result of different definitions of the concept of risk and thus often different assessments of the magnitude of the riskiness of a given action or technology, rather

than differences in opinions about acceptable levels of risk.

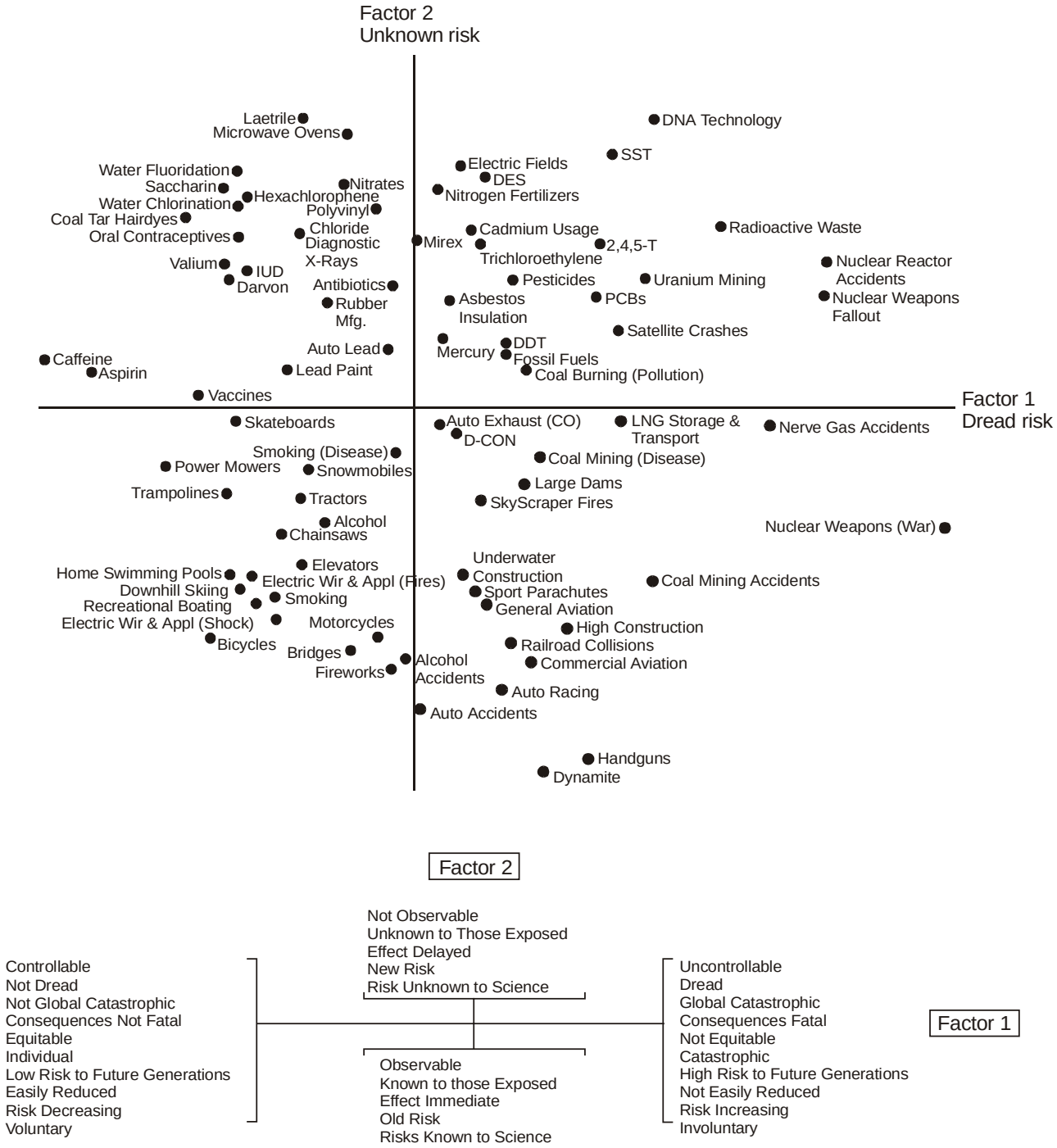

Figure 3. Location of 81 hazards on Factors 1 and 2 derived from the interrelationships among 15 risk characteristics. Each factor is made up of a combination of characteristics, as indicated by the lower diagram. Source: Slovic (1987).

3.2 Perceptions Have Impacts: The Social Amplification of Risk

Perceptions of risk and the location of hazard events within the factor space shown in Figure 3 play a key role in a process labeled social amplification of risk (Kasperson et al., 1988). Social amplification is triggered by the occurrence of an adverse event, which could be a major or minor accident, a discovery of pollution, an outbreak of disease, an incident of sabotage, and so on that falls into the either risk-unknown or risk-previously-ignored category and has potential consequences for a wide range of people. Through the process of risk amplification, the adverse impacts of such an event sometimes extend far beyond the direct damages to victims and property and may result in massive indirect impacts such as litigation against a company or loss of sales, increased regulation of an industry, and so on. In some cases, all companies within an industry are affected, regardless of which company was responsible for the mishap. Thus, the event can be thought of as a stone dropped in a pond. The ripples spread outward, encompassing first the directly affected victims, then the responsible company or agency, and, in the extreme, reaching other companies, agencies, or industries (See Figure 4). Examples of events resulting in extreme higher-order impacts include the chemical manufacturing accident at Bhopal, India, the disastrous launch of the space shuttle Challenger, the nuclear-reactor accidents at Three Mile Island and Chernobyl, the adverse effects of the drug Thalidomide, the Exxon Valdez oil spill, the adulteration of Tylenol capsules with cyanide, and, most recently, the terrorist attack on the World Trade Center and the deaths of several individuals from anthrax. An important aspect of social amplification is that the direct impacts need not be too large to trigger major indirect impacts. The seven deaths due to the Tylenol tampering resulted in more than 125,000 stories in the print media alone and inflicted losses of more than one billion dollars upon the Johnson & Johnson Company, due to the damaged image of the product (Mitchell, 1989). The ripples resulting from several deaths due to anthrax have been even more costly than the Tylenol incident.

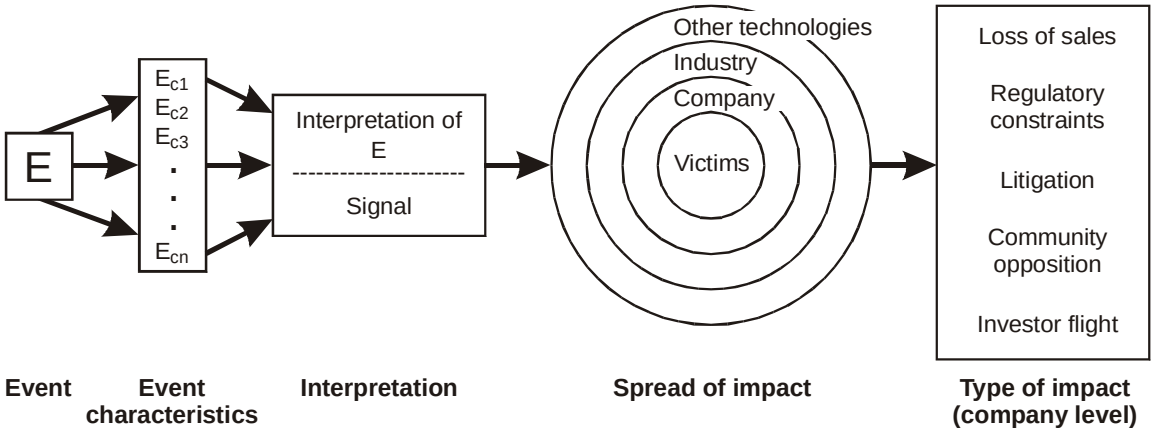

Figure 4. A model of impact for unfortunate events.

Multiple mechanisms contribute to the social amplification of risk. One such mechanism arises out of the interpretation of unfortunate events as clues or signals regarding the magnitude of the risk and the adequacy of the risk-management process (Burns et al., 1990; Slovic, 1987). The informativeness or signal potential of a mishap, and thus its potential social impact, appears to be systematically related to the perceived characteristics of the hazard. An accident that takes many lives may produce relatively little social disturbance (beyond that caused to the victims' families and friends) if it occurs as part of a familiar and well-understood system (e.g., a train wreck). However, a small incident in an unfamiliar system (or one perceived as poorly understood), such as a nuclear waste repository or a recombinant DNA laboratory, may have immense social consequences if it is perceived as a harbinger of future and possibly catastrophic mishaps.

The concept of accidents as signals helps explain our society's strong response to terrorism. Because the risks associated with terrorism are seen as poorly understood and catastrophic, accidents anywhere in the world may be seen as omens of disaster everywhere, thus producing responses that carry immense psychological, socioeconomic, and political impacts.

One implication of the signal concept is that effort and expense beyond that indicated by a cost-benefit analysis might be warranted to reduce the possibility of "high-signal events."

Unfortunate events involving hazards in the upper right quadrant of Fig. 3 appear particularly likely to have the potential to produce large ripples. As a result, risk analyses involving these hazards need to be made sensitive to these possible higher order impacts. Doing so would likely bring greater protection to potential victims as well as to companies and industries.

4.0 Risk as Feelings

Modern theories in psychology suggest that there are two fundamentally different ways in which human beings process information about the world when they make judgments or arrive at decisions (Chaiken &Trope, 1999; Epstein, 1994; Sloman, 1996; Slovic, Finucane, Peters, & MacGregor, in press). One processing system is evolutionarily older, fast, mostly automatic, and hence not very accessible to conscious awareness and control. It works by way of similarity and associations, including emotions, often serving as an "early-warning" system. The other processing system works by algorithms and rules, including those specified by normative models of judgment and decision making (e.g., the probability calculus, Bayesian updating, formal logic), but is slower, effortful, and requires awareness and conscious control. For the rule-based system to operate, we need to have learned the rule. The association/similarity based processing system requires real world knowledge (i.e., more experienced/expert decision makers make better decisions using it than novices in a domain), but its basic mechanisms seem to be hard wired. These two processing systems often work in parallel and, when they do, more often than not result in identical judgments and decisions. We become aware of their simultaneous presence and operation in those situations where they produce different output. Thus, the question of whether a whale is a fish produces an affirmative answer from the similarity-based processing system ("a whale sure looks like a big fish"), but a negative response from the rule based system ("it can't be a fish because it is warm blooded, etc.").

Slovic, Finucane, Peters, & MacGregor (in press) discuss the beneficial aspects of experience or association-based processing in the context of risk, which enabled us to survive during the long period of human evolution and remains the most natural and most common way to respond to threat, even in the modern world. Experiential thinking is intuitive, automatic, and fast. It relies on images and associations, linked by experience to emotions and affect (feelings that something is good or bad). This system transforms uncertain and threatening aspects of the environment into affective responses (e.g., fear, dread, anxiety) and thus represents *risk* as a *feeling*, which tells us whether it's safe to walk down a dark street or drink strange-smelling water (Loewenstein, Weber, et al., 2001). The psychological risk dimensions identified by the psychometric paradigm described in Section 3.0 clearly are mostly affective in nature and the likely result of association-based processing.

Holtgrave and Weber (1993) looked at the relative impact of the two experiential/feeling-based and the rational/rule-based processing systems on people's perceptions of risk. They showed that a hybrid model of risk perception that incorporates both affective variables (dread) and cognitive-consequentialist variables (outcomes and probabilities) provides the best fit for risk perception of situations with uncertain outcomes in both the financial and health and safety domain, suggesting that affective reactions play a crucial role even in seemingly "objective" contexts such as financial investment decisions. Loewenstein, Weber, Hsee, and Welch (2001) similarly document that risk perceptions are influenced by association- and affect-driven processes as much or more than by rule- and reason-based processes. They show that in those cases where the outputs from the two processing systems disagree, the affective, association-based system usually prevails.

Proponents of formal analysis, the newcomer on the risk management scene, tend to view affective responses to risk as irrational. Current wisdom suggests that nothing could be further from the truth. The rational and the experiential system not only operate in parallel, but the former seems

to depend on the latter for crucial input and guidance. Sophisticated studies by neuroscientists have demonstrated that logical argument and analytic reasoning cannot be effective unless it is guided by emotion and affect (see Damasio, 1994). Rational decision making requires proper integration of both modes of thought. Both systems have their own sets of advantages, as well as biases and limitations. The challenge before us is to figure out how to capitalize on the advantages, while minimizing the limitations when we assess risks. Thus, when our feelings of fear move us to consider purchasing a handgun to protect against terrorists, our analytic selves should also heed the evidence showing that a gun fired in the home is 22 times more likely to harm oneself or a friend or family member than to harm an unknown, hostile intruder (Kellerman, et al., 1993).

The relationship and interplay between the two processing modes is further complicated by the fact that it seems to interact with the way people receive information about the magnitude and likelihood of possible events. Experimental studies of human reaction to extreme and usually rare events reveal two robust but apparently inconsistent behavioral tendencies. When decision makers are asked to make a single choice based on the description of possible outcomes of risky choice options and their probabilities, rare events tend to be overweighted as predicted by prospect theory (Kahneman & Tversky, 1979), at least partly because the affective, association-based processing of described extreme and aversive events dominates the analytic processing that would and should discount the affective reaction in proportion to the (low) likelihood of the extreme events occurrence (see, e.g. Rottenstreich & Hsee, 2001). On the other hand, when people learn about outcomes and their likelihood in a purely experiential way (by making repeated choices, starting out under complete ignorance and basing subsequent decisions on previously obtained outcomes), they tend to underweight rare events (Erev, 1998; Barron & Erev, 2002; Weber, Sharoni, & Blais, 2001). This is at least partly a result of the fact that rare events often are not experienced in proportion to their theoretical likelihood in a small number of samples. In those instances where a rare and

extreme event *is* experienced in a small number of samples, one would expect that decision makers would overweight it.

These tendencies are further complicated by our affective response to the consequences of these rare events. The single death of a known individual can tug at our emotions in a powerful way producing a much stronger reaction than the prospect of a large, statistical loss of life. This inability to attach feeling to extreme losses of life, which Fetherstonhaugh et al. (1997) called "psychophysical numbing," is reflected in such sayings as "a single death is a tragedy; a million deaths is a statistic" or "statistics are human beings with the tears dried off."

One of the ways in which the affective processing of a potentially dangerous situation is of value is as a signal that some action needs to be taken to reduce the diagnosed risk. The feeling of fear, dread, or uneasiness will serve as salient and potent reminder to take such action and should remain in place until such action is completed and the "impending danger flag" can be removed. There is a growing body of evidence that this process that is an outgrowth of "risk as feelings" could also benefit from some assistance of "risk as analysis." Weber (1997) coined the phrase *single action bias* for the phenomenon observed in contexts ranging from medical diagnosis to farmers' reactions to climate change that decision makers are very likely to take one action to reduce a risk that they encounter, but are much less likely to take additional steps that would provide additional protection or risk reduction. The single action taken is not necessarily the same for different decision makers, though all have a tendency to stop after taking their single action. The *risk as feelings* interpretation of this phenomenon would suggest that a single action suffices in reducing the feeling of fear or threat. To the extent that a portfolio of responses is called for to manage or reduce a complex risk, it would be beneficial to induce decision makers to engage in more analytic processing.

5.0 Summary and Implications

People's reactions to the events of September 11 and their aftermaths are important illustrations of existing insights into the psychology of risk perception and response to risk. For one, they demonstrate the selective nature of attention to different sources of risk or danger. Richard A. Clarke, former White House counterterrorism chief recently suggested that "democracies don't prepare well for things that have never happened before." The research described in the last section suggests that this is not simply a characteristic of democracies, but of human processing in general. The social amplification of risk, discussed in Section 3.2 can be seen as an ex-post attempt to make up for such failures of anticipation.

The reactions (and, some might argue, overreactions) of public officials to certain, newly diagnosed sources of danger (e.g., box cutters, exploding sneakers) could be seen either as responses that are the result of overestimates of existing dangers on the part of these officials (that are mediated by the recency, vividness, and affective salience of observed threats), or as attempts to provide reassurance to a public, who is known by these officials to fall prey to these biases. Undoubtedly, a well known distinction between felt and attributed responsibility for acts of omission vs. acts of commission also plays a role. While failure to anticipate a theoretically-knowable, but not previously experienced source of danger might be excusable, failure to reduce a known source of risk is certainly not.

Now that we are beginning to appreciate the complex interplay between emotion and reason that is essential to rational behavior, the challenge before us is to think creatively about what this means for managing risks from extreme events. On the one hand, how do we temper the emotion engendered by such events with reason? On the other hand, how do we infuse needed "doses of feeling" into circumstances where lack of experience may otherwise leave us too "coldly rational?"

The ripple effects arising from the social amplification of risks pose other challenges. Building such effects into risk analysis or decision analysis will argue for the adoption of costly preventive measures that would seem unjustifiable if we were only accounting for the costs of direct effects.

Finally, in a world that must deal with "terrorist minds as hazards" we must attempt to understand how such minds process emotion and reason in search of a form of rationality that seems alien to the vast majority of human beings.

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