Perception of Risk Posed by Extreme Events

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Abstract

Extreme events, by definition, cause much harm to people, property, and the natural world. Such events can result from the vagaries of nature (floods or earthquakes) or from technological failure or unintentional human error (Chernobyl or Bhopal). More recently we have witnessed another form of extreme hazard, resulting from terrorism. This paper examines the complex interplay between emotion and reason that drives risk perceptions for extreme events and discusses the need to think creatively about what this means for the management of such risks.

Key words: risk, risk perception, risk assessment, risk management, extreme events

1. Introduction

Extreme events, by definition, cause much harm to people, property, and the natural world. Sometimes such events result from the vagaries of nature, as in the case of floods, earthquakes, or storms, 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, 2002), 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 review is to examine what existing research can tell us about the perception of risk associated with these extreme events and what the characteristics of risk perception might mean for the management of risk posed by extreme events. We will also point out issues that remain in need of exploration.

During the past quarter-century, the field of risk analysis has grown rapidly, supported by research on both risk assessment (the identification, quantification, and characterization of threats to human health and the environment) and risk management (mitigation of such threats and communication about them). The management of extreme events clearly needs to be informed by knowledge about risk assessment from a broad range of perspectives. Risk analysis is a political enterprise as well as a scientific one, and public perception of risk plays an important role in risk analysis, adding issues of values, process, power, and trust to the quantification issues typically considered by risk assessment professionals (Slovic, 1999). Differences in risk perception lie at the heart of many disagreements about the best course of action. Such differences have been demonstrated between technical experts and members of the general public (Slovic, 1987), men vs. women (Finucane, Slovic, 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 paper.

2. What is Risk?

When evaluating public perceptions of risk and their implications for risk management, it is instructive to examine the concept of risk itself. It contains elements of multidimensionality and subjectivity that provide insight into the complexities of public perceptions. A paragraph written by an expert may use the word several times, each time with a different meaning. The most common uses are:

- Risk as a hazard: “Which risks should we rank?”
- Risk as probability: “What is the risk of getting AIDS from an infected needle?”
- Risk as consequence: “What is the risk of letting your parking meter expire?”
- Risk as potential adversity or threat: “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 members of the risk assessment community.

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). *Risk* does not exist "out there," independent of our minds and cultures, waiting to be measured. Instead, it 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. Subjective judgments are involved at every stage of the assessment 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. 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.

3. 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 (e.g., Luce & Weber, 1986). 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.

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. People's quantitative judgments about the perceived and desired riskiness of diverse hazards and the desired level of regulation of each are related to their judgments about other properties, such as (i) the hazard's status on characteristics that have been hypothesized to account for risk perceptions and attitudes (e.g., 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.
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 (e.g., catastrophic potential, fatal outcomes, lack of control) and, as a result, tend to differ from their own (and experts') estimates of annual fatalities.

Psychometric studies show that every hazard has a unique pattern of qualities that appears to be related to its perceived risk. Figure 1, for example, shows the profile across nine characteristic qualities of risk for the public's perception of the risk posed by nuclear power and medical x-rays (Fischhoff et al., 1978). Nuclear power was judged to have much higher risk than medical x-rays and to be in need of much greater reduction in risk before becoming "safe enough." As the figure illustrates, nuclear power also had a much more negative profile across the nine risk characteristics.

Insert Figure 1 here

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 (e.g., hazards rated as "voluntary" tend also to be rated as "controllable" and "well-known;" hazards that appear to threaten future generations tend also to be seen as having catastrophic potential). Factor analysis thus can reduce the identified set of risk characteristics to a smaller set of higher-order factors.

The factor space presented in Figure 2 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 as 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. Given the factor space in Figure 2, the perceived risk of the terrorist attacks of September 11 and the subsequent anthrax attacks in the U.S. would almost certainly place them into the extreme upper-right quadrant.

Laypeople's risk perceptions and attitudes are closely related to the position of a hazard within the factor space. Most important is the "Dread" Factor. The higher a hazard's score on this factor (i.e., the further to the right it appears in the space), the higher is 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 these factors, but closely related to expected annual mortality (Slovic et al., 1979). Many conflicts between experts and laypeople regarding the acceptability of particular risks are the result of differences in the definition of the perceived magnitude of risk of a given action or technology, rather than differences in opinions about acceptable levels of risk.

Insert Figure 2 here

Perceptions Have Impacts: The Social Amplification of Risk

Perceptions of risk and the location of hazard events within the factor space of Figure 2 play a key role in a process labeled the *social amplification of risk* (Kasperson et al., 1988). Social amplification is triggered by the occurrence of an adverse event (e.g., an accident, the outbreak of a disease, or an incident of sabotage) that falls into the risk-unknown or risk-previously-ignored category and has potential consequences for a wide range of people. Risk amplification is analogous to dropping a stone in a pond as shown in Figure 3. The ripples spread outward, encompassing first the direct victims, but then reach the responsible company or agency, and, in the extreme, other companies, agencies, or industries. Indirect impacts are the result of reactions that include litigation against the responsible company, loss of sales, or increased regulation of an industry. In some cases, all companies within an industry may be affected, regardless of which company was responsible for the mishap. Examples 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 large to trigger huge indirect impacts. The seven deaths due to the Tylenol tampering (which resulted in more than 125,000 stories in the print media alone) inflicted losses of more than one billion dollars upon the Johnson & Johnson Company, due to the damaged image of the product (Mitchell, 1989).

Insert Figure 3 here

Multiple mechanisms contribute to the social amplification of risk. One such mechanism arises out of the interpretation of adverse events as clues or signals regarding the magnitude of the risk and the adequacy of the risk-management process and is thus related to the "Unknown Risk" factor (Burns et al., 1990; Slovic, 1987). The signal potential of a mishap, and thus its potential social impact, appears to be systematically related to the risk profile 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 or incidents as signals helps explain the strong response to terrorism. Because the risks associated with terrorism are seen as poorly understood and catastrophic, terrorist incidents anywhere in the world may be seen as omens of future disaster everywhere, thus producing responses that have 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." Adverse events involving hazards in the upper right quadrant of Figure 2 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 the possibility of higher order impacts. Doing so would likely bring greater protection to potential direct victims as well as indirect victims such as companies and industries.

4. 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, 2002a). 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 explicitly. The association/similarity-based processing system requires real world knowledge (i.e., experienced decision makers make better decisions using it than novices), 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").

Experience- or association-based processing in the context of risk, because of its automaticity and speed, has 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 (Slovic, Finucane, Peters, & MacGregor, 2002a). 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, Hsee, & Welch, 2001). The psychological risk factors described in Section 3.0 clearly are mostly affective in nature and likely have their impact on perceived risk as the result of association-based processing.

A study of risk perception of risky behaviors in both the financial and health/safety domain showed that affective reactions play a crucial role even in seemingly “objective” contexts such as financial investment decisions (Holtgrave & Weber, 1993). A hybrid model that incorporated both affective variables (dread) and cognitive-consequentialist variables (outcomes and probabilities) provided the best fit to the perception of risk in both the financial and health/safety domain, suggesting 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 risk analysis 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 modes of processing have their own set of advantages, as well as biases and limitations. The challenge before us is to design risk assessment methods and procedures that capitalize on the advantages, while minimizing the limitations and to integrate the outputs of the two modes. At an individual level, this might mean to integrate feelings of fear which might move us to consider purchasing a handgun to protect against invaders with analytic considerations of evidence that a gun fired in the home is 22 times more likely to harm oneself or a friend or family member than an unknown, hostile intruder (Kellerman, et al., 1993).

Another example of fruitful integration is more policy-relevant. One way in which the affect generated by 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 may remain in place until an action is taken 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 a wide range of contexts (e.g., medical diagnosis, farmers' reactions to climate change) that decision makers are very likely to take some action to reduce a risk that they encounter, but are much less likely to take additional steps that would provide incremental protection or risk reduction. The single action taken is not necessarily the most effective one, nor is it the same for different decision makers. However, regardless of which single action is taken first, decision makers have a tendency to stop further action, presumably because the first action suffices in reducing the feeling of fear or threat. To the extent that a portfolio of responses is required to manage or reduce a complex risk, it would be beneficial to induce decision makers to engage in more analytic processing.

The relationship and interplay between the two processing modes is further complicated by the fact that it seems to be contingent on the way people receive information about the magnitude and likelihood of possible events (Hertwig, Barron, Weber, & Erev, 2004; Weber, Sharoni, & Blais, 2004). 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 choose between risky options based on a description of possible outcomes and their probabilities (provided either numerically [a .01 chance of losing $1000, otherwise nothing] or in the form of a graph or pie chart), rare events tend to be overweighted as predicted by prospect theory (Kahneman & Tversky, 1979). This happens at least in part 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 (Loewenstein et al., 2001; Rottenstreich & Hsee, 2001). When people, on the other hand, 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; Hertwig et al., 2004; Weber et al., 2004). This happens in part because 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 expects decision makers to overweight it.) It also happens because experiential learning places greater weight on recent rather than more distant events, and rare events have a small chance of occurring in the recent past (Hertwig et al., 2002).

5. Summary and Implications

Reactions to the events of September 11 and their aftermaths are important illustrations of phenomena well known to students of risk perception and the psychology of 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.” Research on the underweighting of rare events when knowledge about their occurrence comes purely from direct experience, described Section 4 suggests that this is not simply a characteristic of democracies, but of human processing in general. The social amplification of risk model, 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 newly diagnosed sources of danger (e.g., box cutters, exploding sneakers) may either be 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 attempts to provide assurance to a public that is known by these officials to fall prey to these biases. Better knowledge of the psychological mechanisms giving rise to public fears should contribute to more effective as well as cost-effective interventions in the latter case. 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 certainly is 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 direct 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. What is needed is a defensible basis for allocating finite risk management funds that takes into consideration both direct and indirect effects of the full range of known and foreseeable extreme events, while being cognizant that public perceptions of risk may differ from expert estimates but have their own legitimacy and can lead to a broad range of objective consequences (e.g., fear-induced stress kills).

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. Insights that reduce the seeming unpredictability of the occurrence of future terrorist attacks and their scope and targets will have large impact on public assurance, since they will provide input to both cognitive and affective responses to such risks.

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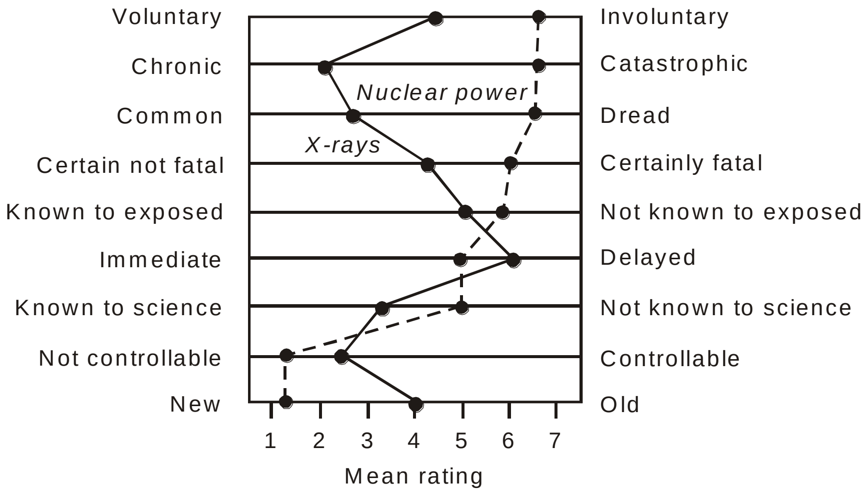

Figure 1. Qualitative characteristics of perceived risk for nuclear power and X-rays across nine risk characteristics. Source: Fischhoff et al., 1978.

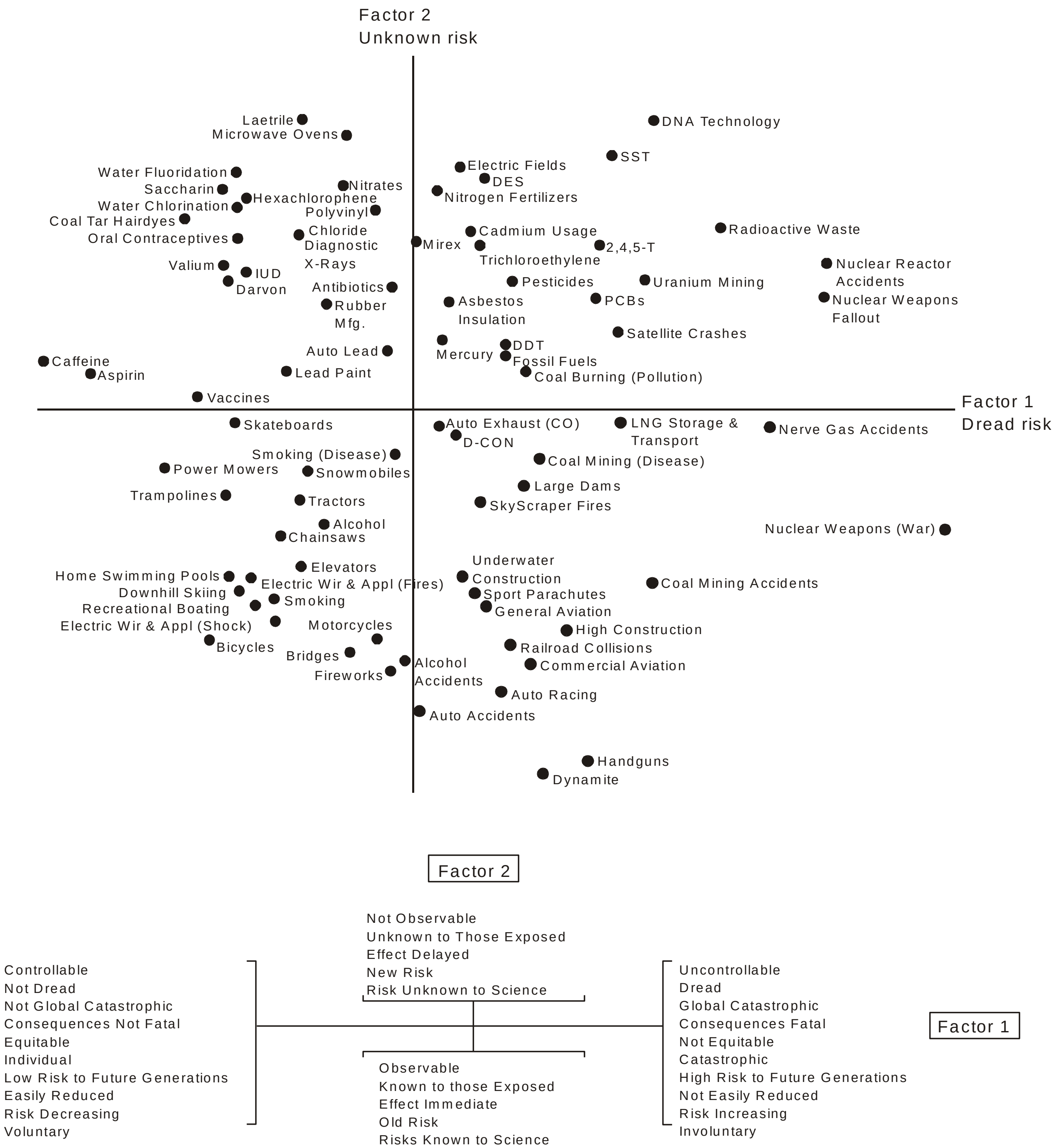

Figure 2. Location of 81 hazards on Factors 1 and 2 derived from the interrelationships among 15 risk characteristics. Each factor is made up of a combination of characteristics, as indicated by the lower diagram. Source: Slovic (1987).

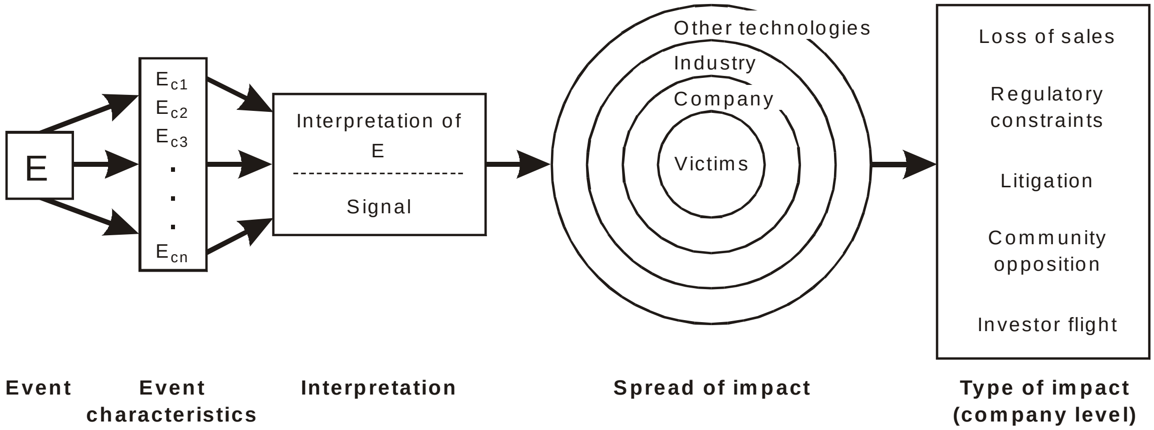

Figure 3. A model of impact for unfortunate events. Source: Slovic (1987).