The Psychometric Study of Risk Perception

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Introduction

In industrialized societies, the question "How safe is safe enough?" has emerged as a major policy issue of the 1980s. The frequent discovery of new hazards and the widespread publicity they receive is causing more and more individuals to see themselves as the victims, rather than as the beneficiaries, of technology. These fears and the opposition to technology that they produce have perplexed industrialists and regulators and led many observers to argue that the public's apparent pursuit of a "zero-risk society" threatens the nation's political and economic stability (Harris, 1980; Wildavsky, 1979).

In order to understand this problem, a number of researchers have begun to examine the opinions that people express when they are asked, in a variety of ways, to evaluate hazardous activities and technologies. This research has attempted to develop techniques for assessing the complex and subtle opinions that people have about risk. With these techniques, researchers have sought to discover what people mean when they say that something is (or is not) "risky," and to determine what factors underlie those perceptions. If successful, this research should aid policy makers by improving communication between them and the lay public, by directing educational efforts, and by predicting public responses to new hazards, events (e.g., a good safety record, an accident), and management strategies (e.g., warning labels, regulations, substitute products). A broad agenda for this research includes the following questions:

(1) What are the determinants of "perceived risk?" What are the concepts by which people characterize risks? How are those concepts related to their attitudes and behavior towards different technologies? To what extent are risk perceptions affected by emotional factors? For example, are they really sensitive, as is often claimed, to perceived controllability of risks and the dread they evoke? How adequate are the methods used to study perceptions of risk?

(2) How accurate are public perceptions? When laypeople err, is it because they are poorly informed or because they were unable to do better? Are people so poorly informed (and uneducable) that they require paternalistic institutions to protect them? Would they be better off letting technical experts make most of the important decisions? Or do they know enough to be able to make their own decisions in the marketplace? When experts and laypeople disagree about risk, is it always the latter who are in error?

(3) What steps are needed to foster enlightened behavior with regard to risk? What information do policy makers and the public need? How should such information be presented? What indices or criteria are useful for putting diverse risks in perspective? How can the news media and the schools help to educate people about risk and its management?

(4) What is the role of judgment in technical assessments of risk? When experts are forced to go beyond hard evidence and rely

on educated intuition, do they encounter judgmental difficulties similar to those experienced by laypeople? How well do experts assess the limits of their own knowledge? How can technical judgments be improved?

(5) How do people perceive the benefits of risky technologies? Almost all questions asked about risk perceptions have analogs with benefit perceptions.

(6) What determines the relative acceptability of hazardous technologies? How are assessments of their various risks and benefits combined subjectively? What role do considerations such as voluntariness, catastrophic potential, and equity play? What risk-benefit considerations motivate people to political action? Are some kinds of risks unacceptable, no matter what benefits they are expected to bring?

(7) What makes a risk analysis "acceptable?" Some analyses are able to guide society's responses, whereas others only fuel debate. Are these differences due to the specific hazards involved, the political philosophy underlying the analytical methods, the way that the public is involved in the decision-making process, the results of the analysis, or the manner in which the results are communicated? Can policy makers responsibly incorporate social values into risk analysis?

(8) How can polarized social conflict involving risk be reduced? Can an atmosphere of trust and mutual respect be created among opposing parties? How can we design an environment in which

effective, multi-way communication, constructive debate, and compromise can take place?

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, 1982), which uses psychophysical scaling and multivariate analysis techniques to produce quantitative representations or "cognitive maps" 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 (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.

The remainder of this paper briefly reviews some of the results obtained from psychometric studies of risk perception, including some previously unreported results. In doing so, it examines a few of the methodological and substantive issues surrounding the basic approach and outlines some potentially fruitful directions for future research.

Previous Work

Revealed and Expressed Preferences

The original impetus for the psychometric paradigm came from the pioneering effort of Starr (1969) to develop a method for weighing technological risks against benefits in order to answer the fundamental question "How safe is safe enough?" His revealed preference approach assumed that, by trial and error, society has arrived at an "essentially optimum" balance between the risks and benefits associated with any activity. One may therefore use historical or current risk and benefit data to reveal patterns of "acceptable" risk-benefit tradeoffs. Examining such data for several common industries and activities, Starr concluded that (a) acceptability of risk from an activity is roughly proportional to the third power (cube) of the benefits for that activity and (b) the public will accept risks from voluntary activities (e.g., skiing) that are roughly 1,000 times greater than it would tolerate from involuntary hazards (e.g., food preservatives) that provide the same level of benefit.

The merits and deficiencies of Starr's approach have been debated at length (see, e.g., Fischhoff, Lichtenstein, Slovic, Derby

& Keeney, 1981). We shall not go into them here, except to note that concern about the validity of the many assumptions inherent in the revealed preferences approach stimulated Fischhoff et al. (1978) to conduct an analogous psychometric analysis of questionnaire data, resulting in expressed preferences. In recent years, numerous other studies of expressed preferences have been carried out within the psychometric paradigm (see, for example, Brown & Green, 1980; Gardner, Tiemann, Gould, DeLuca, Doob & Stolwijk, 1982; Green, 1980; Green & Brown, 1980; Johnson & Tversky, in press; Lindell & Earle, 1982; MacGill, 1982; Renn, 1981; Slovic, Fischhoff & Lichtenstein, 1980a, in press-b; Tiemann & Tiemann, 1983; Vlek & Stallen, 1981; von Winterfeldt, John & Borcherding, 1981).

Although the results of these studies differ somewhat, they 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 1). They have also shown that the concept "risk" means different things to different people. When experts judge risk, their responses correlate highly with technical estimates of annual fatalities. Laypeople can assess annual fatalities if they are asked to (and produce estimates somewhat like the technical estimates). However, their judgments of "risk" are sensitive to other factors as well (e.g., catastrophic potential, threat to future generations) and, as a result, tend to differ from their own (and experts') estimates of annual fatalities.

Insert Table 1 about here

Another consistent result from psychometric studies of expressed preferences is that people tend to view current risk levels as unacceptably high for most activities. The gap between perceived and desired risk levels suggest that people are not satisfied with the way that market and other regulatory mechanisms have balanced risks and benefits. Across the domain of hazards, there seems to be little systematic relationship between perceived existing risks and benefits. However, studies of expressed preferences do seem to support Starr's claim that people are willing to tolerate higher risks from activities seen as highly beneficial. But whereas Starr concluded that voluntariness of exposure was the key mediator of risk acceptance, expressed preference studies have shown that other characteristics such as familiarity, control, catastrophic potential, equity, and level of knowledge also seem to influence the relationship between perceived risk, perceived benefit, and risk acceptance (see, e.g., Fischhoff et al., 1978; Slovic et al., 1980a).

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

Factor Analytic Representations

Many of the qualitative risk characteristics are 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 appear 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 shown that the broader domain of characteristics can be condensed to a small set of higher-order characteristics or factors.

The factor spaces presented in Figures 1 and 2 have been replicated across groups of laypersons and experts judging large and diverse sets of hazards. The factors in this space reflect the degree to which a risk is understood and the degree to which it evokes a feeling of dread. A third factor, reflecting the number of people exposed to the risk, has been obtained in several studies. Making the set of hazards more specific (e.g., partitioning nuclear power into radioactive waste transport, uranium mining, nuclear reactor accidents, etc.) has had little effect on the factor structure or its relationship to risk perceptions (Slovic, Fischhoff & Lichtenstein, in press-b).

Insert Figures 1 and 2 about here

The story that has emerged from factor-analytic studies of perceived risk has been so consistent that one is tempted to believe in its universality. However, there are additional facets to the story, as indicated by other recent studies. For example, Tiemann and Tiemann (1983) used a factor-analytic technique that allowed them to study individual differences in risk and benefit orientations toward a set of hazards. Four major themes (or cognitive maps) emerged from these analyses, allowing subjects to be categorized as (1) benefit oriented, (2) risk oriented, (3) trade-off oriented, or (4) polarized. The trade-off respondents perceived some activities as both risky and highly beneficial and other activities as both low in risk and low in benefits. The polarized individuals saw activities having high benefit as having low risk and vice versa.

Similarity-based representations

Whereas factor-analytic studies provide respondents with a predetermined set of risk characteristics to rate, an alternative approach asks for ratings of the overall similarity between pairs of hazards. Multidimensional scaling techniques are then used to derive a dimensional representation of the similarity space. Multidimensional scaling of similarity judgments for small sets of hazards by Vlek and Stallen (1981) and Green and Brown (1980) has produced two-dimensional representations similar to those obtained in our factor-analytic studies. However, Vlek and Stallen found substantial individual differences in the weighting of the dimensions.

Johnson and Tversky (in press) have compared factor analytic and similarity representations derived from the same set of 18 hazards. The hazards differed from those in Figures 1 and 2 in that they included natural hazards and diseases as well as activities and technologies. They found that the factor space derived from this set of hazards resembled the space derived from earlier studies.

However, they found that the space obtained from the multidimensional scaling of similarity judgments differed from the factor analytic space. Further analysis showed that judgments of similarity based on direct comparisons of hazards were, in most cases, quite different from similarity indices obtained by comparing the hazards across the set of characteristics supplied by the experimenter. For example, homicide was judged to be similar to other acts of violence (war, terrorism) despite having a very different profile on the various risk characteristics. Although similarity judgments are not constrained by characteristics selected by the researcher, they may be susceptible to influence from considerations that are not relevant to risk. Thus Hutchinson (1980) found that nuclear power and non-nuclear electric power were judged quite similar, perhaps because of their common element of power production.

In addition to producing a multidimensional representation of the similarity data, Johnson and Tversky constructed a tree representation (Figure 3). The risks are the terminal nodes of the tree and the distance between any pair of risks is given by the length of the horizontal parts of the shortest path that joins them; the vertical part is included only for graphical convenience. Figure 3 exhibits a distinct hierarchy of clusters which Johnson and Tversky called: hazards, accidents, violent acts, technological disasters and diseases.

Insert Figure 3 about here

Implications of Psychometric Research

The social and policy implications of this research have been a matter of lively debate, taking up most of the June, 1982 issue of the journal, Risk Analysis. Douglas and Wildavsky (1982), argued that psychometric studies, with their cognitive emphasis, ignore the social processes that play a major role in determining which risks society fears and which it ignores. Otway and Thomas (1982) have taken a particularly cynical view, arguing that this research is being used as a tool in a discourse which is not concerned with risks per se, nor with perceptual and cognitive processes. Rather, the hidden agenda is the legitimacy of decision-making institutions and the equitable distribution of hazards and benefits.

Our view (Slovic, Fischhoff & Lichtenstein, 1982) is that an understanding of how people think about risk has an important role in informing policy, even if it cannot resolve all questions. Moreover, risk perception research can be used to challenge social-political assumptions as well as to reinforce them (e.g., Fischhoff, Slovic & Lichtenstein, 1983). The psychometric studies described above provide the beginnings of a psychological classification system for hazards that may help explain and forecast reactions to specific technologies, such as nuclear power or genetic engineering (e.g., Slovic, Lichtenstein & Fischhoff, in press) or provide guidelines for managing the social conflicts surrounding hazardous technologies (von Winterfeldt & Edwards, 1983). For example, even the present rudimentary state of knowledge about mental representations of hazards has proven relevant for evaluating proposed safety goals for nuclear power (Fischhoff, 1983; Slovic, Fischhoff & Lichtenstein, in press-a).

As for the different representations that have been derived from different methods of analysis, it now seems apparent that there is no one way to model risk perception, no universal cognitive map. People maintain multiple perspectives on the world of hazards. What remains to be determined is how these diverse perspectives influence their attitudes and behaviors. For example, we have found that, for laypeople, both the level of perceived risk associated with a particular hazard and attitudes towards regulating these risks can be predicted quite well from knowledge of where that hazard falls within the space derived from factor analysis (see Figure 4). Most important is the factor "Dread Risk." The higher a hazard's score on this factor, 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. Expert's perceptions of risk, however, seem much less closely related to the factor space. Instead, experts appear to focus on expected annual mortality when judging riskiness and, presumably, when considering the need to regulate (Hohenemser, Kates & Slovic, 1983; Slovic, Fischhoff & Lichtenstein, 1979). As a result, some conflicts over "risk" may result from experts and laypeople having different definitions of the concept.

Insert Figure 4 about here

Johnson and Tversky (in press) hypothesize that similarity-based representations may play an important role in predicting people's responses to new risks or to new evidence about risk. For example, the Tylenol poisoning appeared to provoke fears concerning over the counter drugs but not other products (such as foods) that could easily be subject to tampering. They also speculated that the similarity between nuclear power and nuclear warfare might fuel much of the public debate about the acceptability of nuclear power reactors.

Current Research

Our most recent work has used psychometric techniques to investigate three distinct topics. The first study considers how the social consequences of an accident are affected by the number of deaths it causes. The second study examines the concept of risk and the possibility of constructing a comprehensive measure of risk. The third study addresses an important methodological question, regarding the degree to which cognitive representations derived from analyses of group mean data across diverse hazards can be generalized to individuals' perceptions of particular hazards.

Modeling the Societal Impact of Fatal Accidents

A frequently asked question in the application of formal analysis to safety decisions is: "How should a single accident that takes N lives be weighted relative to N accidents, each of which takes a single life?" Because safety resources are limited, assigning disproportionate weight to multiple-fatality accidents would emphasize prevention of such accidents at the cost of increasing the risk from smaller accidents.

In our approach to this problem (Slovic, Lichtenstein & Fischhoff, in press), we followed Keeney's (1980) distinction between the personal impacts of a fatal accident and the societal impacts. The former include the pain, suffering, and economic hardship of the victims and their friends and relatives, whereas the latter include the public distress and the political, social, and economic turmoil that may result from an accident. Our focus was on the societal impacts.

A number of proposals have been put forth regarding the proper way to model the societal impact of fatal accidents. Most of these describe the social cost of losing N lives in a single accident as a function of N^{α}. A common view is that a single large accident is more serious than many small accidents producing the same number of fatalities, hence $\alpha > 1$.

The complex nature of risk perception revealed in the psychometric studies made us doubt that any simple function of N could adequately capture the societal importance of a fatal accident. Perhaps the most dramatic anecdotal evidence in support of these doubts comes from the societal response to the accident at the Three Mile Island (TMI) nuclear reactor in 1979. Although it caused no immediate deaths and is expected to produce few if any latent cancer fatalities, this accident has greatly affected the structure and the viability of the entire nuclear power industry (Evans and Hope, 1982). Its enormous societal impact would never have been predicted by the N^α model or any other model based solely on the number of fatalities.

Reflection on the factor-analytic model in Figure 1 and 2 suggests that, although the N^α model may capture some aspect of Factor 1, the dread evoked by an event, it does not consider Factor 2, the degree to which the risks are thought to be known or understood. As a result, we hypothesized that one ingredient missing in the N^α models is recognition of the role that accidents play in providing information about possible future trouble. Thus, the social impact of an accident may be large, regardless of its death toll, if the accident shows the hazard to be poorly understood and, hence, signals a large increase in its risk. In this view, the accident at TMI was seen as an informative and ominous signal, raising fears that this technology was not understood well enough to be adequately under control. As a result, the accident led to a strong sociopolitical reaction whose consequences (stricter regulation of the nuclear industry, reduced operation of reactors worldwide, increased costs of reactor construction and operation) dwarfed the more direct costs (possible latent cancers, property damage, repairs, cleanup), significant as these were.

The potential importance of viewing accidents as signals goes beyond the domain of nuclear power. The generality of this concept is demonstrated by a study (reported by Slovic, Fischhoff & Lichtenstein, 1980a) in which we asked 21 women (median age = 37) to rate the seriousness of 10 hypothetical accidents. Several aspects of seriousness were rated, including:

(a) The total amount of suffering and grief caused by the loss of life in each mishap;

(b) The number of people who need to be made aware of the mishap via the media;

(c) The amount of effort (and money) that should be put into investigating the cause of the mishap and preventing its recurrence; and

(d) The degree to which hearing about the mishap would cause one to be worried and upset during the next few days.

Respondents also rated the informativeness of these incidents, defined as the degree to which the mishap told them (and society) something that may not have been known about the hazardousness of the specific activity.

The accidents were constructed so as to vary with respect to total fatalities and informativeness (see Table 2). The five less-informative accidents represented incidents that were generated by reasonably familiar and understood processes. The more informative mishaps were designed to signal a change in riskiness (perhaps caused by a breakdown in the system controlling the hazard) and some potential for the proliferation of similar mishaps. For example, a bus skidding on ice represented a low-information mishap because its occurrence did not signal a change in motor-vehicle risks (except for a limited time at that site), whereas an accident caused by a poorly designed steering system in a new model automobile would be informative about all such vehicles.

Insert Table 2 about here

In general, the personal impacts of an accident, as measured by the amount of suffering and grief attributed to it, was found to be closely related to the number of people killed. All other (societal) aspects of perceived seriousness were, however, more closely related to the accident's information content. Accidents signaling a possible breakdown in safety control systems and the possibility of proliferation were judged more worrisome and in need of both greater awareness and greater public effort to prevent reoccurrence. The number of people killed was not related to these aspects of seriousness.

To test our speculation about the relationship between accident impact and the risk factors, we conducted a second study comparing ratings of informativeness and seriousness with the location of the hazard within the factor structure shown in Figure 2. Our stimuli were 30 hazards, distributed across the four quadrants of the factor space. From the high dread, high unknown quadrant, we selected hazards such as DNA technology, nuclear reactors, orbiting space satellites, and radioactive waste. Highly unknown but not dread hazards included microwave ovens, contraceptives, water chlorination, and antibiotics. Known and dread hazards included coal mining, nerve gas, dams, and commercial aviation. Known but not dread hazards included power mowers, bicycles, automobiles, and recreational boating.

The participants in this study were 78 university students who rated each hazard according to the degree to which an accident taking 1 or 2 lives "serves as a warning signal for society, providing new information about the probability that similar or even more destructive mishaps may occur within this type of activity." The participants also rated the overall "seriousness" of an accident involving each of those hazards (holding fatalities and other damages constant).

Each hazard is represented, in Figure 5, by a point whose size reflects its mean rating of signal potential. It is apparent that the judged signal potential of a hazard is closely related to location within the space. Signal potential correlated with the "dread" factor (r=.58), the "unknown" factor (r=.71), and their linear combination (r=.92). It also correlated .94 with mean ratings of the overall seriousness of an accident.

Insert Figure 5 about here

This analysis has led us to a number of specific conclusions. First, the societal impact of fatal accidents cannot be modeled solely by a function of N. As a result, models based on such functions should not be used to guide policy decisions.

Second, accident impact models need to consider signal potential. Unlike N^{α} models, which reflect attitudes regarding how deaths are clustered, signal potential involves an informational variable that should be central to any reasonable planning analysis.

Third, the concept of accidents as signals helps explain society's strong response to some nuclear power mishaps. Because reactor risks tend to be perceived as poorly understood and catastrophic, accidents with few direct casualties may be seen as omens of disaster, thus producing indirect or "ripple" effects resulting in immense costs to the industry and to society. One implication of signal value is that great effort and expense might be warranted to minimize the possibility of small but frightening reactor accidents.

Finally, when attempting to model the societal impacts of high signal-value accidents, we see no alternative but to elaborate the various events and consequences that may result from such accidents, the consequences of those consequences, the probabilities of all these direct and higher-order effects, and some measures of their costs. Although such detailed modeling may appear unmanageably complex, even a rough attempt to anticipate possible higher-order consequences of an accident is preferable to the use of simpler models with known inadequacies. Psychometric studies may enable analysts to forecast which classes of accidents will be the most potent signals, hence most in need of complex modeling.

Defining Risk

Technical experts tend to view risk as synonymous with mortality and morbidity. This is evident not only in their responses to psychometric surveys (Slovic, Fischhoff & Lichtenstein, 1979), but in the ways that they conduct risk analyses (U.S. Nuclear Regulatory Commission, 1975) and in the presentations they create to "put risks in perspective." These presentations typically involve elaborate tables and even "catalogs of risk" in which some unidimensional index of death or disability is displayed for a broad spectrum of life's hazards. These indices include risks per hour of exposure (Sowby, 1965), annual probabilities of death (Wilson, 1979) and reductions in life expectancy (Cohen & Lee, 1979; Reissland & Harries, 1979). Those presenting these data typically assume that such information will aid decision makers, even though such comparisons have no logically necessary implications for the acceptability of risks (Fischhoff et al., 1981).

Psychometric studies of perceived risk imply that mortality and morbidity statistics will not, by themselves, be satisfactory indices of risk. People's perceptions and attitudes are determined by a variety of quantitative and qualitative characteristics such as those underlying Figure 2. Attempts to characterize, compare, and regulate risks must be sensitive to the broader conception of risk that underlies people's concerns.

We shall describe next a recent attempt by Fischhoff, Watson, and Hope (in press) to demonstrate a general approach for constructing a more adequate definition of risk. Such an index cannot dictate decisions but can provide necessary input to them, along with measures of non-risk costs and benefits. Other uses for an index of risk would be to educate one's intuition, set standards, help agencies allocate resources for risk management and help institutions evaluate and defend their actions (Fischhoff, in press; Watson, 1983).

Fischhoff et al. emphasized that the definition and measurement of risk is inherently controversial, because of the value issues raised in specifying the concept and the power of those specifications to influence important decisions. Furthermore, no one definition is correct, or suitable, for all problems. Choice of a definition is a political act, reflecting the perceived importance of different adverse effects in a particular situation. As a result, choosing a measure for risk should not be the exclusive province of scientists, who have no special insight into what society should value. The approach suggested by Fischhoff et al. is, therefore, general enough to be adjusted to diverse problems and value systems.

The approach was demonstrated within the context of evaluating energy technologies. Its first step is determining what consequences should be included in the measure. The illustrative index included mortality, concern, and morbidity. Mortality risks were subdivided into risks to the general public and risks to workers. Concern was similarly partitioned into two dimensions based upon psychometric studies: unknown risk and dread risk. The former expresses aversion to uncertainty. The latter captures a risk's ability to evoke a visceral response.

The next step is to aggregate these components into an overall measure of risk. Here Fischhoff et al. relied on multiattribute utility theory (Keeney & Raiffa, 1976), which provides a framework for determining the relative weights (tradeoffs) among the various components and integrating them into a single numerical index. Given the validity of certain assumptions, it becomes possible to express the risk index R in terms of the equation

$$R = \sum_i w_i x_i$$

where x_i is the measure on component i and w_i is the weight for that component.

Fischhoff et al. presented a detailed application of this technique in the context of evaluating energy technologies. The application demonstrated how sensitive the overall index of risk is to the component attributes included in the definition of risk and to the weights assigned judgmentally to these attributes. As a result, the relative riskiness of these technologies depends upon what is meant by "risk." The analysis was not intended to produce a "correct" definition--which is a practical and political matter. Rather, it pointed to the issues that must be addressed if a politically acceptable and logically sound measure is to be created. In addition, it offered a highly flexible methodology with which to address these issues. Because the process of defining and measuring risks requires a variety of explicit value judgments, the present analysis highlights the need for effective public debate about what sorts of consequences are legitimate components of "risk."

Modeling the Perception of Individuals

Psychometric studies grew out of an interest in understanding why the risks from some hazardous activities appeared to be treated differently from the risks of other activities. In most of these studies, after many subjects have evaluated many technologies, the mean rating for each technology and each risk aspect, calculated across subjects, becomes the unit of analysis. Thus information about how individuals differ is lost, in return for a more stable look at differences between technologies.

From these studies a theory of risk perception has emerged: lay people's risk judgments are based not just on their beliefs about fatalities, but also on their beliefs about several risk characteristics such as the technologies' catastrophic potential, dreadedness, and severity of consequences should an accident occur. Further, people's desire for reduction of risk seems closely related to their perception of how much risk now exists.

If this theory is valid for a group, it should also be valid for many of the individuals in the group. Further, it may be that a number of people all share the same theory yet differ in their judgments of the risk characteristics of a particular hazard. For example, some people may not consider pesticides risky because they believe that pesticides do not present any catastrophic potential, whereas others who perceive such potential in pesticides will judge them as highly risky.

This possibility suggests that the unit of analysis be single individuals' ratings of risk aspects. As Gardner et al. (1982) have pointed out, there is no logical necessity that the relationships found across hazards will also be found within a single hazard across individuals. However, if such similarities were to be found, the theory would be strengthened and expanded. Additionally, we would have a better understanding of the so-frequently observed disagreements among members of our society about the risk of hazards such as nuclear power. Finally, adopting the individual as the unit of analysis would enable researchers to study the effect of individual differences such as level of education or attitudes about the effectiveness of governmental intervention on risk perception.

Countering these advantages are difficulties encountered in using the individual-differences approach. First, occasional mistakes or carelessness in ratings can produce an error component large enough to obscure genuine relationships among the ratings. This source of error is lessened when the ratings are averaged across individuals. A second source of error comes from individual differences in the way people use response scales. For example, one person may feel very strongly about some things yet is reluctant to use extreme numbers, while another person whose beliefs are more neutral may make finer discriminations and thus tend to use extreme responses. Finally, variation in beliefs across individuals is a necessary (although not sufficient) condition for detecting correlations. If all respondents, for example, believe that nuclear power is a dreaded technology and thus give it a high rating on the scale of dreadedness, this scale cannot show a correlation with perceived risk when the correlation is computed across individuals. If the tested group is homogeneous, individual analysis will fail even if the theory is true.

In designing a study to explore individual differences in perceptions of the risk of nuclear power, Gardner et al. (1982) recognized the need for a maximal variation in opinions. Their subjects included Sierra Club members, students, carwash attendants, Rotary Club members, and nuclear power engineers. Using many of the same scales as had been used in cross-hazard research, they found, in correlations across 367 respondents, many of the same relationships between perceived risk, desired risk, and risk characteristics as were found in the cross-hazard studies by Fischhoff et al. (1978) and Slovic et al. (1979; 1980a). Gardner et al. concluded that the similarity of results was noteworthy, given the differences in the procedures that produced them.

Pursuing this question, we have reexamined some of our original data, looking at correlations between perceived risk, desired risk reduction, and risk characteristics across individuals within hazards. The subjects were the 95 laypeople whose responses were previously used in grouped, cross-hazard analyses reported by Slovic et al. (in press-b). The subjects came from three groups: members of the League of Women Voters and their spouses, members of the Active Club (a business and professional group), and college students. For the present analyses the three subgroups were combined.

For each of the 30 hazards listed in Table 1, individual judgments of the riskiness of the hazard were correlated, across the subjects, with ratings, for that hazard, of nine risk characteristics (e.g., voluntariness, immediacy of effects) and with a measure of desire for reduction in the risk of that hazard. Thus for each hazard the individual risk ratings were correlated with 10 other variables, as listed in Table 3.

Insert Table 3 about here

In order to reduce the possible effects of response bias, all 11 variables were standardized before the correlations were computed. The original risk measure was a ratio-scale judgment in which the subjects assigned a score of 10 to whichever hazard the subject believed was least risky; other hazards were judged relative to that least-risky hazard. For the present analysis, the risk judgments were ranked, within each individual across the 30 hazards, and these rank scores were used in the correlations. The original risk characteristic measures were seven-point rating scales. For each of these 9 scales, each individual's ratings were transformed by a linear function that produced a new scale with mean of 0 and standard deviation of 1 across the 30 hazards. These standard scores were used for the correlations. The original measure of desire for risk reduction was a ratio judgment. A judgment greater than 1.0 indicated that "serious action, such as legislation to restrict its practise, should be taken [to reduce the risk]"; a judgment less than 1.0 meant that "the risk of death could be higher than it is now before society would have to take serious action" (Fischhoff et al., 1978, p. 132). These adjustment factors were ranked across hazards for each individual for the present analysis.

Results of the within-hazard analyses are shown in Table 3. For comparison, the first column presents the cross-hazard correlations based on the same data. For these cross-hazard correlations, the variables were not standardized. For perceived risk and desire for risk reduction, geometric means were taken across the 95 subjects; for the 9 risk characteristics, mean ratings were used.

In the cross-hazard analyses, perceived risk correlated most highly with dread and severity of consequences and secondarily with catastrophic potential, all key components of the dread factor that emerged from the factor analyses of these data. Also, perceived risk correlated highly (.81) with desired risk reduction.

The second column of Table 3 presents a summary of the individual-difference analyses: The mean of the 30 correlations for each variable. For the first 6 variables, these means accurately summarize the lack of correlation found across all 30 hazards. Only one of these correlations exceeded .30: for Pesticides, perceived risk correlated -.32 with voluntariness, indicating that, to a slight degree, those who viewed exposure to pesticides as more involuntary also viewed them as more risky.

The mean correlation of .11 for catastrophic potential reflects, in part, the many hazards with little possibility of catastrophe; individual differences thus did not appear in the catastrophe ratings of these hazards. Four hazards showed correlations in the .30's: Nuclear Power, Non-nuclear Electric Power, Antibiotics, and Spray Cans.

The dread variable was correlated .20 or greater with perceived risk for 13 of the 30 hazards; the severity of consequences variable showed such correlations for 22 hazards. As suggested by the mean of .43, the measure of desire for risk reduction was consistently related to perceived risk; for only two hazards was the correlation less than .20. Thus for most hazards, those people who believed a hazard was more risky also believed that there was a greater need for risk reduction.

The last two columns show the individual-difference correlations for Nuclear Power and Bicycles. The former is typical of the hazards for which individual differences were found. The latter illustrates the lack of correlation in hazards having only small individual differences.

In sum, the present analysis provides modest support for the application of risk perception theory to individual differences. As expected, the correlations were low. Because of the problems associated with within-hazard correlational studies, it might be more fruitful to use a quite different design to study the attributes of risk perception in individuals. This possibility is explored in the next section.

Issues for Future Research

Although much progress has been made toward understanding the nature and implications of risk perception, we still lack definitive answers to the lengthy list of questions presented in the introduction to this paper. One obvious need is to conduct psychometric surveys of the general population and special populations of interest (such as hazard victims, technical experts, neighbors of hazardous facilities, legislators, journalists, and activists). Cross-national surveys would also be of interest. Some of this broader sampling is currently underway, as indicated by the accompanying chapters in this section. Among the many research directions worth pursuing, we shall concentrate here on three: designing new approaches to modeling cognitive representations of risk, extending the factor-analytic approach, and moving toward educating people, rather than just studying them.

New Methods for Modeling Risk Perceptions

The previous section discussed the possibilities and limitations of modeling the perceptions of individuals with correlational methods. Other techniques may be applied to this problem. One that has proven useful elsewhere is the analysis-of-variance approach to capturing judgmental policies (Anderson, 1981; Slovic & Lichtenstein, 1971). This approach starts by identifying a set of critical characteristics or dimensions. Next, a set of stimulus items (hazards in this case) are constructed in terms of their status on these various dimensions or characteristics. Thus item (hazard) x_1 might be defined in terms of its catastrophic potential (y_1), the level of scientific uncertainty regarding its risks(y_2), the dread it evokes (y_3), some aspects of its benefits (y_4, y_5, ... , y_i) and other dimensions selected by the researcher ($y_{i+1}...y_n$). The items are constructed so that across the set, any pair of dimensions (y_j,y_k) are uncorrelated. Factorial combinations of the stimulus dimensions are used to accomplish this. Each individual judges every hazard in the set on some criterion variable such as riskiness or acceptability of risk, after which analysis of variance methods are used to model the relative importance of each stimulus dimension in producing the overall judgments.

This general approach has been used to model a wide variety of judgments (Slovic & Lichtenstein, 1971; Hammond, Stewart, Brehmer & Steinmann, 1975; Anderson, 1981). The advantage here is that the same basic design can be used to model the importance of hazard characteristics in determining judgments both across hazards and within hazards. In fact, the identical set of stimuli (hazard profiles) could be used in both studies. For example, to study individual perceptions of a single hazard, the various profiles could be said to represent the assessments of different individuals each viewing the same hazard. The subject would be asked to predict how each of these individuals would judge the criterion (say risk) from knowledge of the way that individual perceived the hazard profile. In the cross-hazard design, these same stimuli would be said to represent different hazards. The subject would be asked to judge their riskiness (or rate how others would judge their riskiness). Thus models describing the importance of various hazard characteristics could be derived on the basis of judgments about the same stimuli under two different cover stories. Comparison of the resulting models would indicate whether or not the cross-hazard judgments and the within-hazard judgments appeared to be generated in the same way. Of course, there are many variations possible with this basic design. For example, one might name the hazards and vary those names, holding the hazard characteristics constant, to see whether the model people use to weight and combine the characteristics varies as a function of the type of hazard being evaluated.

One limitation of the analysis-of-variance approach is that it sometimes creates combinations of characteristics that may not exist in reality and, hence, may be hard to judge. A second limitation is that it asks people to judge a rather abstract profile. A feature that the analysis of variance approach shares with the factor-analytic approach is that the researcher forces the respondent to consider a set of well-defined characteristics when judging each hazard. This feature is a strength if the set spans the universe of important characteristics, a weakness if it does not. Similarity-based techniques do not specify the characteristics for the respondents, and should be used to supplement the more structured methods. Another supplementary technique is the <u>repertory grid</u>, used to study hazards by Green and Brown (1980). Respondents were shown three hazards and were asked to indicate a characteristic that two of the hazards shared with each other but not with the third. An extensive set of characterisics was generated by this method, including many not studied previously. The repertory grid could be used as a starting point for factor-analytic or analysis of variance studies.

The repertory grid is one of a larger class of "free-response" techniques, which allow respondents to generate their own response alternatives. Earle and Lindell (in press) have used such open-ended survey questions to study public perceptions of hazardous industrial facilities. Although many of their results replicate those from studies using structured response alternatives, they obtained some important new findings as well. One was that their respondents exhibited no spontaneous concern for future generations, in contrast to the concern shown in factor analytic studies that explicitly forced consideration of this variable. Other possibilities lie in the family of "process-tracing" techniques, which attempt to make explicit the detailed operations people employ when making a judgment or decision (Raaij, 1983; Svenson, 1979). These methods require people to "think aloud" or search for information as they make their judgments. In this way, the characteristics that people deem important can be "observed" without having first been primed by the researcher.

There is, obviously, no method for modeling cognitive processes that does not have some disadvantage. The choice depends upon the particulars of the scientific or policy problem being addressed. In many cases, several techniques will have to be used in concert in order to get a comprehensive picture of risk perceptions.

Elaborating Factor-Analytic Representations

Within the factor-analytic paradigm, one important topic is to look further at the generality of the recurrent two-factor structure shown in Figures 1 and 2. To date, this structure has been found with heterogeneous sets of hazards, selected in a variety of ways. An open question, of both theoretical and practical significance, is whether the structure would also pertain to a set of hazards all falling within the same category. For example, one point in both figures represents the item "railroads." But all railroad accidents are not the same. They differ with regard to:

- Type of accident
  - collisions
  - derailments
  - fires or explosions
- Cause of accident
  - unknown
  - mechanical failure
  - operator error
  - environmental problem (e.g., mudslide)
- Nature of consequences
  - deaths
  - injuries
  - property damage
  - environmental damage

If a diverse set of railroad mishaps were judged on the various risk characteristics, would the same two- or three-factor space emerge as was obtained across the broader domain of hazards? With whatever space emerged, could the social cost or seriousness of an accident be predictable on the basis of where it falls within the factor space (as in Figure 5)? Such a possibility would be extremely useful for setting safety standards or addressing such specific design questions as: What sort of safety systems, at what cost, should a company install on a rail line going through a long mountain tunnel? How would different types of rail accidents, causing about equal damage to people and the environment, be perceived? How costly would they be to the railroad company? The same general sorts of questions could be raised about other classes of hazards such as genetic engineering or space flight.

Educating risk perceptions

Research to date has taken risk perception as a given fact of life that policy makers must anticipate, satisfy, and cope with. The results of this research, however, suggest a number of possibilities for aiding people's intuitive perceptions. These possibilities should be pursued in the interests of increasing the applied potential of this work.

If the two-factor solution is interpreted as an indication of how people naturally think about hazards, then it provides a framework for presenting them with the information they need to participate in risk-management decisions. Thus, they should feel a need for good information about how well a hazard is known to science and the extent of its catastrophic potential. If people examine accident reports for their signal value, then methods are needed to assess informativeness and communications techniques are needed to express it meaningfully.

The multivariate character of risk that has emerged in psychometric studies suggests that there are many things to be considered when thinking about "risk" and many incommensurable factors to bear in mind when assessing the relative riskiness of different hazards. The need for some convenient summary measure of risk seems apparent. The attempt to develop a general purpose index of risk was intended to address that need. Although reliance on multiattribute utility theory ensured the conceptual soundness of that effort, empirical research is needed to establish its practicality. Can people provide the explicit judgments needed to create such an index? If an index is created, can people absorb the information that it summarizes in a way that will be meaningful? Even if they endorse the index in principle, will they be willing to accept decisions based upon it? Would they feel more comfortable being shown, in matrix form, the information that it summarizes, leaving them to perform the integration in their heads?

An important theme in the psychometric literature has been establishing why lay and expert perceptions of risk differ. As described earlier, one cause of these differences is in the definitions of risk that lay people and experts use. Once these sources of disagreement have been clarified, one can examine the accuracy of lay perceptions regarding those aspects of risk that are of importance to them. In some cases, lay people's disagreements with experts can be defended (e.g., on grounds of their having access to information that the experts lack, or their being more sensitive to the inconclusiveness in current scientific knowledge than those who produce it). When lay people's views cannot be defended, it becomes important to provide them with the information needed to make decisions in their own best interests (Fischhoff, in press; Slovic, Fischhoff & Lichtenstein, 1980b). The foundation of knowledge laid by psychometric studies could serve as the springboard for research showing how best to communicate risk information and improve people's perceptions.

Conclusions

Individual and societal response to hazards is obviously multidetermined. Political, social, economic, psychological and technical factors interact in complex and as yet incompletely understood ways to produce this response. Nevertheless, research aimed at understanding how people think about risk can play an important role in guiding policy decisions. Psychometric techniques seem capable of highlighting the concerns of people at risk and forecasting reactions to hazards and their management. The knowledge provided by these techniques may prove essential to helping people cope with the risks they face in their daily lives and ensuring the success of risk-management policies at the societal level.

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Table 1

Ordering of Perceived Risk 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.)

	League of Women Voters	College Students	Active 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 & 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

Source: Slovic, Fischhoff, and Lichtenstein, 1981.

Table 2

Accident Scenarios Designed to Vary in Informativeness

Low Information Value	High Information Value
Bus skids on ice and runs off road (27 killed)	Nuclear reactor accident: Partial core meltdown releases radiation inside plant but not outside (1 killed)
Dam collapse (40 killed)	Botulism in well-known brand of food (2 killed)
Hundred year flood (2,700 killed)	New model auto steering fails (3 killed)
Meteorite hits stadium (4,000 killed)	Recombinant DNA workers contract mysterious illness (10 killed)
Two jumbo jets collide on runway (600 killed)	Jet engine falls off on take off (300 killed)

Source: Slovic, Fischhoff & Lichtenstein, 1980b.

Table 3

Correlates of Perceived Risk

Variable	Correlations across 30 hazards	Correlations within hazards		
		Mean	Nuclear Power	Bicycles
Voluntariness	-.05	-.08	-.20	-.15
Immediacy	.09	.04	-.01	.08
Known to exposed	.24	.00	-.24	-.08
Known to science	.24	.01	.02	-.13
Controllability	-.07	-.09	-.14	.10
Familiarity	.05	-.09	-.01	.04
Catastrophic Potential	.30	.11	.32	.08
Dread	.68	.19	.24	.07
Severity (consequences fatal)	.71	.26	.37	.16
Desire for Risk Reduction	.81	.43	.58	.48

Figure Captions

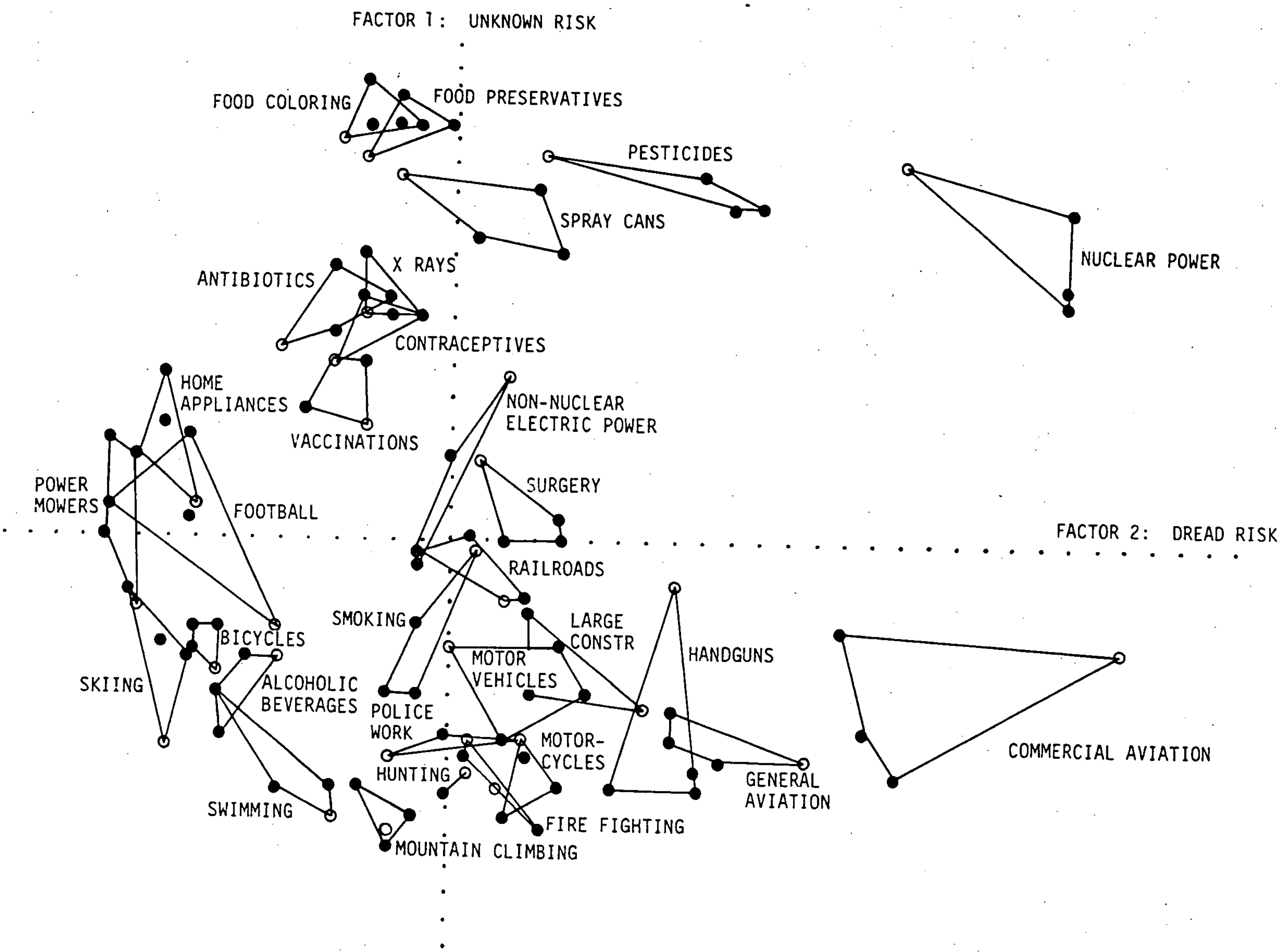
1. Location of 30 hazards within the two-factor space obtained from League of Women Voters, student, Active Club, and expert groups. Connected lines join or enclose the loci of four group points for each hazard. Open circles represent data from the expert group. Unattached points represent groups that fall within the triangle created by the other three groups. Source: Slovic, Fischhoff & Lichtenstein, 1981.

2. Hazard locations on Factors 1 and 2 derived from the interrelationships among 18 risk characteristics. Each factor is made up of a combination of characteristics, as indicated by the lower diagram. Source: Slovic, Fischhoff & Lichtenstein, in press-b.

3. Tree representation of causes of death. Source: Johnson & Tversky, in press.

4. Attitudes towards regulation of the hazards in Figure 2. The larger the point, the greater the desire for strict regulation to reduce risk.

5. Relation between signal potential and risk characterization for 30 hazards in Figure 2. The larger the point, the greater the degree to which an accident involving that hazard was judged to "serve as a warning signal for society, providing new information about the probability that similar or even more destructive mishaps might occur within this type of activity." Source: Slovic, Lichtenstein & Fischhoff, in press.



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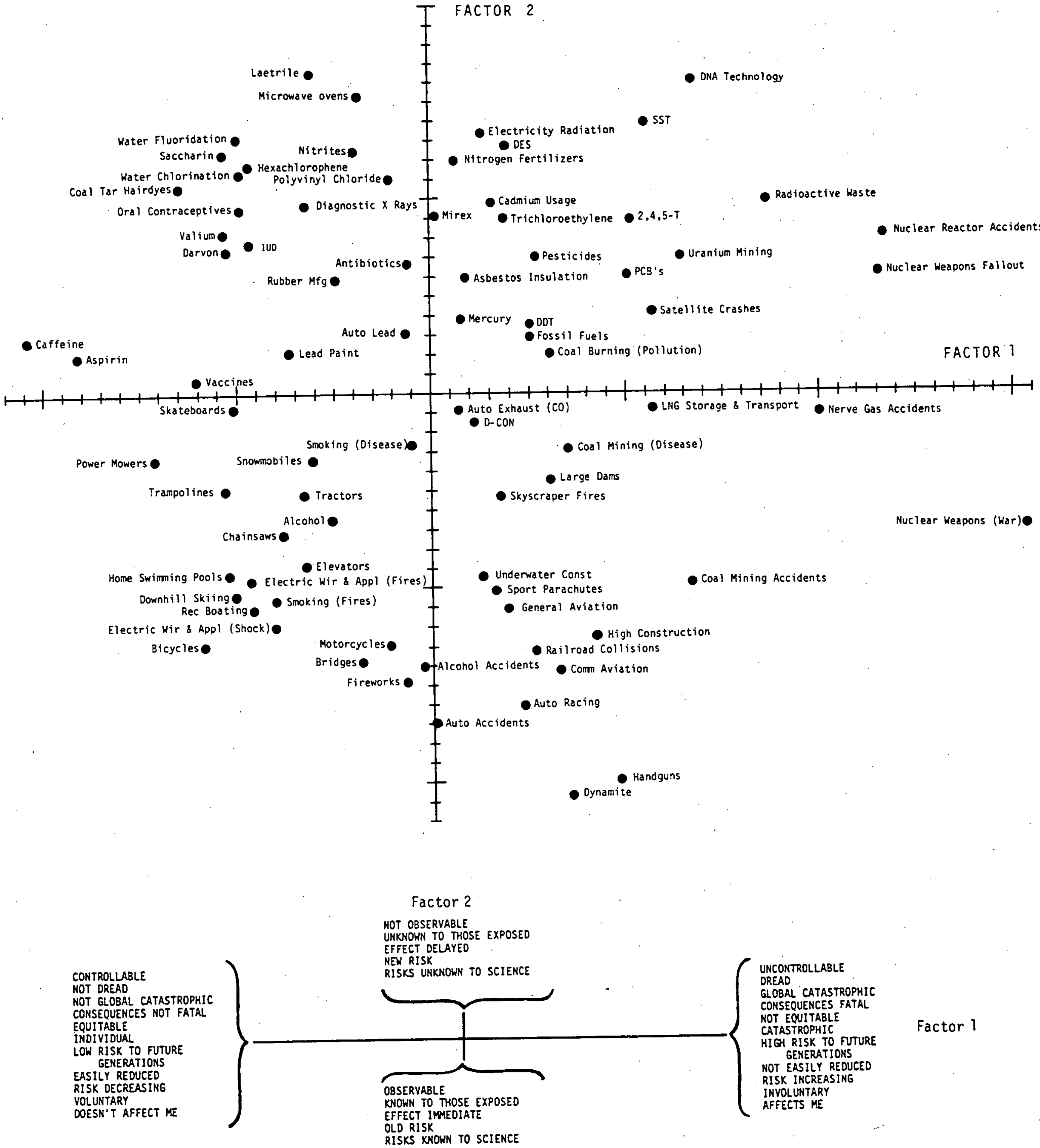

Figure 2. Hazard locations on Factors 1 and 2 derived from the interrelationships among 18 risk characteristics. Each factor is made up of a combination of characteristics, as indicated by the lower diagram. Source: Slovic, Fischhoff & Lichtenstein, in press-b.

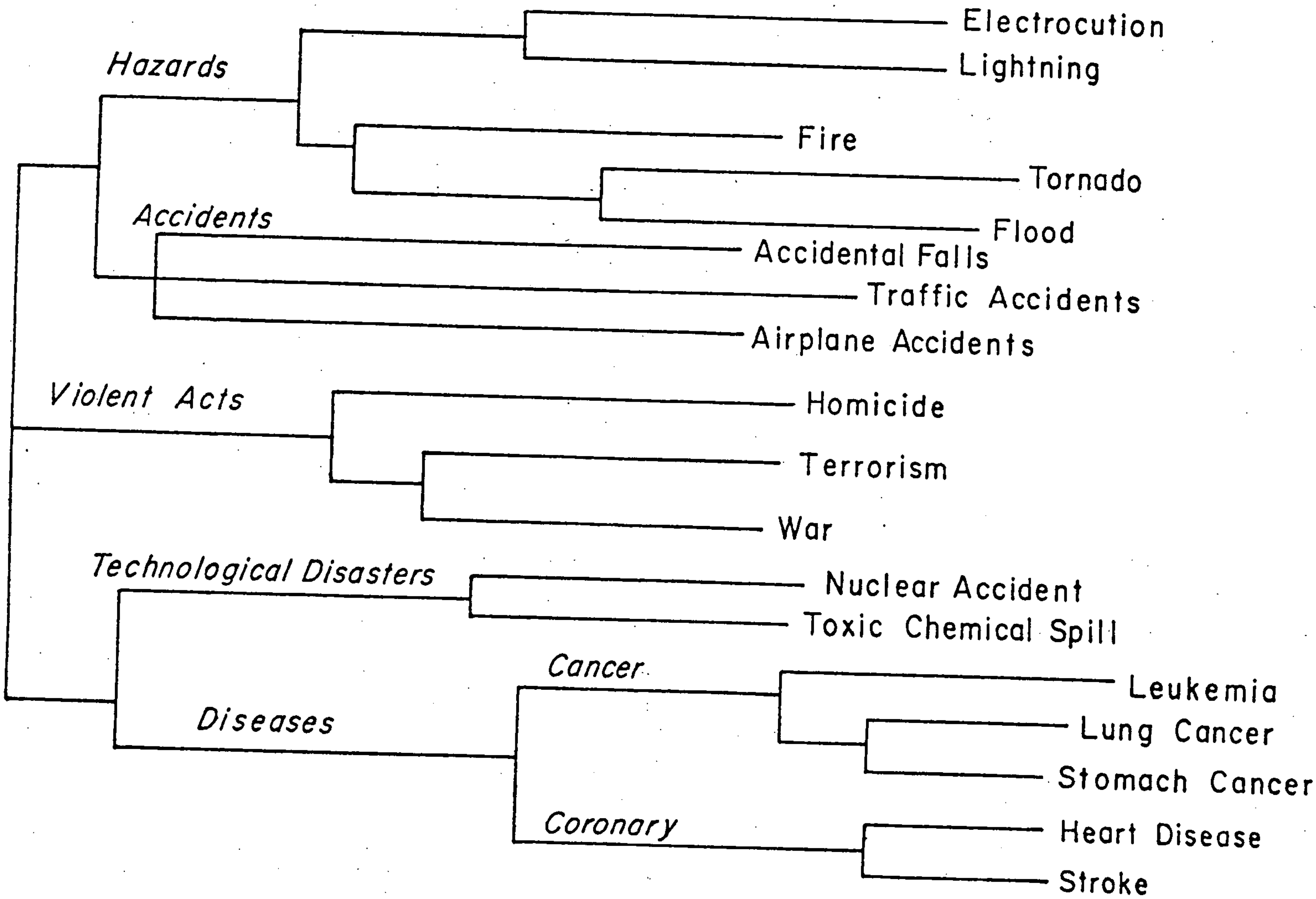

Figure 3. Tree representation of causes of death.
Source: Johnson & Tversky, in press.

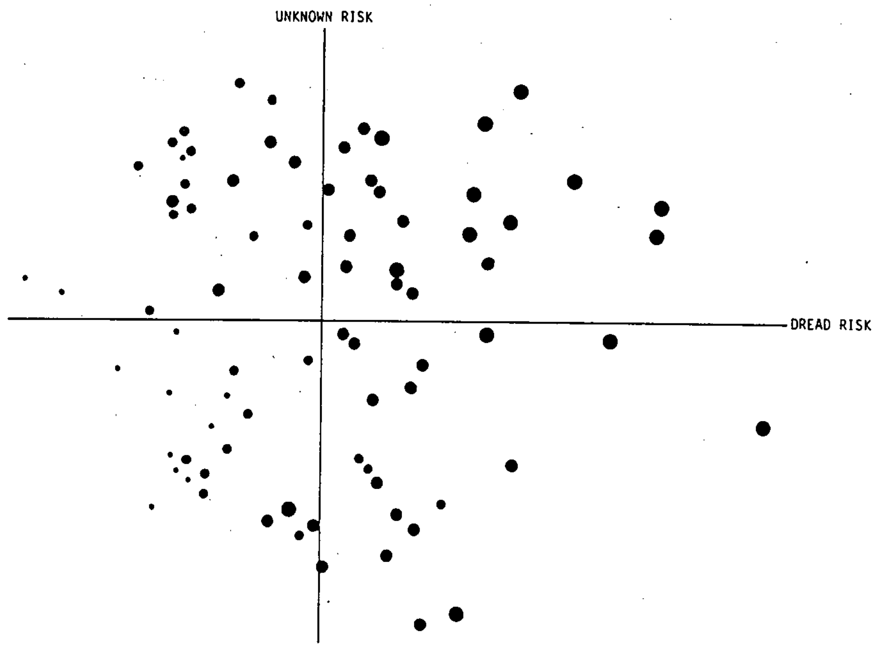

Figure 4. Attitudes towards regulation of the hazards in Figure 2. The larger the point, the greater the desire for strict regulation to reduce risk.

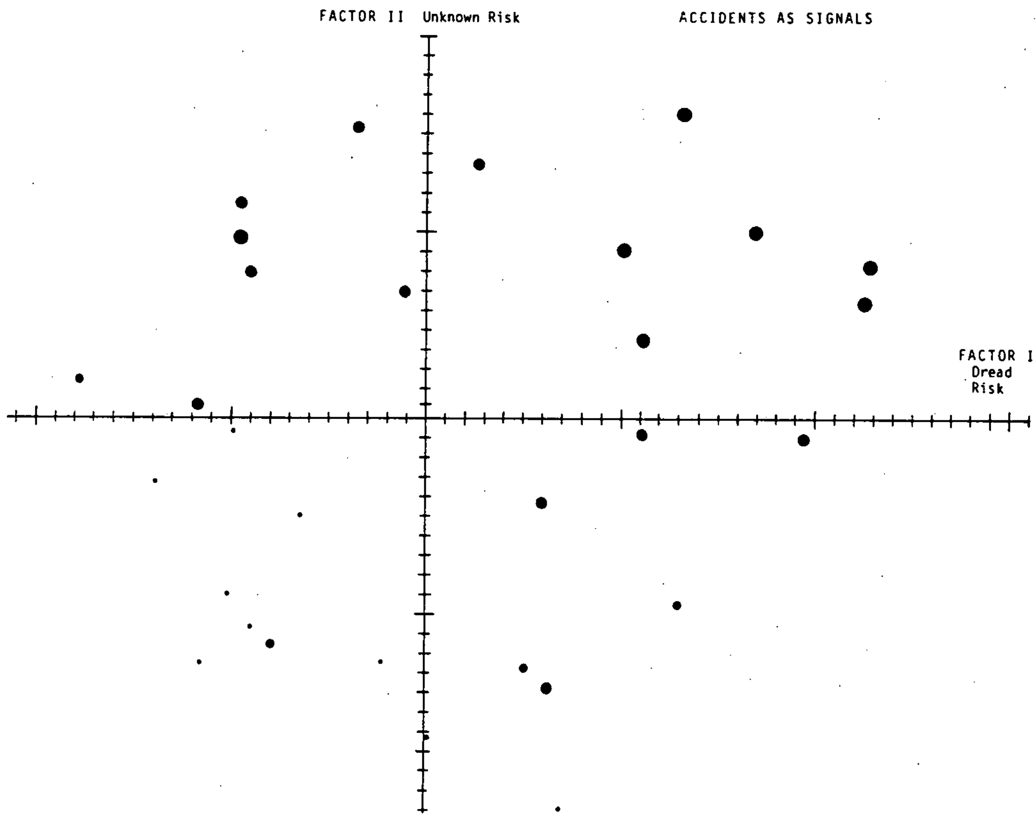

Figure 5. Relation between signal potential and risk characterization for 30 hazards in Figure 2. The larger the point, the greater the degree to which an accident involving that hazard was judged to "serve as a warning signal for society, providing new information about the probability that similar or even more destructive mishaps might occur within this type of activity." Source: Slovic, Lichtenstein & Fischhoff, in press.