RATING THE RISKS: THE STRUCTURE OF EXPERT AND LAY PERCEPTIONS

Paul Slovic, Baruch Fischhoff & Sarah Lichtenstein
Decision Research
A Branch of Perceptronics
1201 Oak Street
Eugene, OR 97401

ABSTRACT

The management and regulation of high-risk technologies need to be based on an understanding of the ways in which people think about risk. Without such understanding, well-intended laws and policies may be ineffective, or even counterproductive. To this end, recent studies of risk perception have examined the opinions people express when they are asked, in various ways, to characterize and evaluate hazardous activities and technologies. This research aims to aid risk analysis and societal decision making by (i) improving methods for eliciting opinions about risk, (ii) providing a basis for understanding and anticipating public responses to hazards, and (iii) improving the communication of risk information among laypeople, technical experts, and policy makers. This paper describes the results of these studies and examines their implications for risk assessment.

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People respond to the hazards they perceive. If their perceptions are faulty, efforts at public and environmental protection are likely to be misdirected. In order to improve hazard management, a risk assessment industry has developed over the last decade which combines the efforts of physical, biological, and social scientists in an attempt to identify hazards and measure the frequency and magnitude of their consequences (1).

For some hazards extensive statistical data are readily available; for example, the frequency and severity of motor vehicle accidents are well documented. For other familiar activities, such as the use of alcohol and tobacco, the hazardous effects are less readily discernible and their assessment requires complex epidemiological and experimental studies. But in either case, the hard facts go only so far and then human judgment is needed to interpret the findings and determine their relevance for the future.

Other hazards, such as those associated with recombinant DNA research or nuclear power, are so new that risk assessment must be based on theoretical analyses such as fault trees (see Figure 1), rather than on direct experience. While sophisticated, these analyses, too, include a large component of human judgment. Someone, relying on educated intuition, must determine the structure of the problem, the consequences to be considered, and the importance of the various branches of the fault tree.

Once performed, the analyses must be communicated to the various people, including industrialists, environmentalists, regulators, legislators, and voters, who are actually responsible for dealing with the hazards. If these people do not see, understand, or believe these risk statistics, then distrust, conflict, and ineffective hazard management may result.

Judgmental Biases

When lay people are asked to evaluate risks, they seldom have statistical evidence on hand. In most cases they must rely on inferences based on what they remember hearing or observing about the risk in question. Recent psychological research has identified a number of general inferential rules that people seem to use in such situations (2). These judgmental rules, known technically as heuristics, are employed to reduce difficult mental tasks to simpler ones. Although valid in some circumstances, in others they can lead to large and persistent biases with serious implications for risk assessment.

Availability

One heuristic that has special relevance for risk perception is known as "availability" (3). People who use this heuristic judge an event as likely or frequent if instances of it are easy to imagine or recall. Frequently occurring events are generally easier to imagine and recall than rare events. Thus, availability is often an appropriate cue. Availability, however, is also affected by numerous factors unrelated to frequency of occurrence. For example, a recent disaster or

a vivid film such as The China Syndrome may seriously distort risk judgments.

Availability-induced errors are illustrated by several recent studies in which we asked college students and members of the League of Women Voters to judge the frequency of various causes of death, such as smallpox, tornadoes, and heart disease (4). In one study, these people were told the annual death toll (50,000) for motor vehicle accidents in the United States; they were then asked to estimate the frequency of forty other causes of death. In another study, participants were given two causes of death and asked to judge which of the two is more frequent. Both studies showed people's judgments to be moderately accurate in a global sense; that is, people usually knew which were the most and least frequent lethal events. Within this global picture, however, there was evidence that people made serious misjudgments, many of which seemed to reflect availability bias.

Figure 2 compares the judged number of deaths per year with the actual number according to public health statistics. If the frequency judgments were accurate, they would equal the actual death rates, and all data points would fall on the straight line making a 45-degree angle with the axes of the graph. In fact, the points are scattered about a curved line that sometimes lies above and sometimes below the line of accurate judgment. In general, rare causes of death were over-estimated and common causes of death were underestimated. As a result, while the actual death toll varied over a range of one million, average frequency judgments varied over a range of only a thousand.

In addition to this general bias, many important specific biases were evident. For example, accidents were judged to cause as many deaths as diseases, whereas diseases actually take about fifteen times as many lives. Homicides were incorrectly judged to be more frequent than diabetes and stomach cancer. Homicides were also judged to be about as frequent as stroke, although the latter actually claims about eleven times as many lives. Frequencies of death from botulism, tornadoes, and pregnancy (including childbirth and abortion) were also greatly overestimated.

Table 1 lists the lethal events whose frequencies were most poorly judged in our studies. In keeping with availability considerations, overestimated items were dramatic and sensational whereas underestimated items tended to be unspectacular events which claim one victim at a time and are common in nonfatal form.

In the public arena the availability heuristic may have many effects. For example, the biasing effects of memorability and imaginability may pose a barrier to open, objective discussions of risk. Consider an engineer's demonstrating the safety of subterranean nuclear waste disposal by pointing out the improbability of each branch of the fault tree in Figure 1. Rather than reassuring the audience, the presentation might lead individuals to feel that "I didn't realize there were so many things that could go wrong." The very discussion of any low-probability hazard may increase the judged probability of that hazard regardless of what the evidence indicates.

In some situations, failure to appreciate the limits of "available" data may lull people into complacency. For example, we asked people to evaluate the completeness of a fault tree showing the problems that

could cause a car not to start when the ignition key was turned (5). Respondents' judgments of completeness were about the same when looking at the full tree as when looking at a tree in which half of the causes of starting failure were deleted. In keeping with the availability heuristic, what was out of sight was also out of mind.

Overconfidence

A particularly pernicious aspect of heuristics is that people are typically very confident about judgments based on them. For example, in a follow-up to the study on causes of death, participants were asked to indicate the odds that they were correct in their judgment about which of two lethal events was more frequent (6). Odds of 100:1 or greater were given often (25 percent of the time). However, about one out of every eight answers associated with such extreme confidence was wrong (fewer than 1 in 100 would have been wrong if the odds had been appropriate). About 30 percent of the judges gave odds greater than 50:1 to the incorrect assertion that homicides are more frequent than suicides. The psychological basis for this unwarranted certainty seems to be people's insensitivity to the tenuousness of the assumptions upon which their judgments are based (in this case, the validity of the availability heuristic). Such overconfidence is dangerous. It indicates that we often do not realize how little we know and how much additional information we need about the various problems and risks we face.

Overconfidence manifests itself in other ways as well. A typical task in estimating failure rates or other uncertain quantities is to set upper and lower bounds so that there is a 98 percent chance that the true value lies between them. Experiments with diverse groups of people making many different kinds of judgments have shown that, rather than 2 percent of true values falling outside the 98 percent confidence bounds, 20 percent to 50 percent do so (7). People think that they can estimate such values with much greater precision than is actually the case.

Unfortunately, experts seem as prone to overconfidence as lay people. When the fault tree study described above was repeated with a group of professional automobile mechanics, they, too, were insensitive to how much had been deleted from the tree. Hynes and Vanmarcke (8) asked seven "internationally known" geotechnical engineers to predict the height of an embankment that would cause a clay foundation to fail and to specify confidence bounds around this estimate that were wide enough to have a 50 percent chance of enclosing the true failure height. None of the bounds specified by these experts actually did enclose the true failure height. The multi-million dollar Reactor Safety Study (the "Rasmussen Report") (9), in assessing the probability of a core meltdown in a nuclear reactor, used a procedure for setting confidence bounds that has been found in experiments to produce a high degree of overconfidence. Related problems led a review committee, chaired by H. W. Lewis of the University of California, Santa Barbara, to conclude that the Reactor Safety Study greatly overestimated the precision with which the probability of a core meltdown could be assessed (10).

Another case in point is the 1976 collapse of the Teton Dam. The Committee on Government Operations has attributed this disaster to the unwarranted confidence of engineers who were absolutely certain they had solved the many serious problems that arose during construction (11).

Indeed, in routine practice, failure probabilities are not even calculated for new dams even though about 1 in 300 fails when the reservoir is first filled. Further anecdotal evidence of overconfidence may be found in many other technical risk assessments. Some common ways in which experts may overlook or misjudge pathways to disaster include:

(1) Failure to consider the ways in which human errors can affect technological systems. Example: Due to inadequate training and control room design, operators at Three Mile Island repeatedly misdiagnosed the problems of the reactor and took inappropriate actions.

(2) Overconfidence in current scientific knowledge. Example: Use of DDT came into widespread and uncontrolled use before scientists had even considered the possibility of the side effects that today make it look like a mixed and irreversible blessing.

(3) Insensitivity to how a technological system functions as a whole. Example: Though the respiratory risk of fossil-fueled power plants has been recognized for some time, the related effects of acid rains on ecosystems were largely missed until very recently.

(4) Failure to anticipate human response to safety measures. Example: The partial protection offered by dams and levees gives people a false sense of security and promotes development of the flood plain. When a rare flood does exceed the capacity of the dam, the damage may be considerably greater than if the flood plain had been unprotected. Similarly, "better" highways, while decreasing the death toll per vehicle mile, may increase the total number of deaths because they increase the number of miles driven.

Desire for Certainty

Every technology is a gamble of sorts and, like other gambles, its attractiveness depends on the probability and size of its possible gains and losses. Both scientific experiments and casual observation show that people have difficulty thinking about and resolving the risk/benefit conflicts even in simple gambles. One way to reduce the anxiety generated by confronting uncertainty is to deny that uncertainty. The denial resulting from this anxiety-reducing search for certainty thus represents an additional source of overconfidence. This type of denial is illustrated by the case of people faced with natural hazards, who often view their world as either perfectly safe or as predictable enough to preclude worry. Thus, some flood victims interviewed by Kates (12) flatly denied that floods could ever recur in their areas. Some thought (incorrectly) that new dams and reservoirs in the area would contain all potential floods, while others attributed previous floods to freak combinations of circumstances unlikely to recur. Denial, of course, has its limits. Many people feel that they cannot ignore the risks of nuclear power. For these people, the search for certainty is best satisfied by outlawing the risk.

Scientists and policy-makers who point out the gambles involved in societal decisions are often resented for the anxiety they provoke. Borch (13) noted how annoyed corporate managers get with consultants who give them the probabilities of possible events instead of telling them exactly what will happen. Just before a blue-ribbon panel of scientists reported that they were 95 percent certain that cyclamates do not cause cancer, Food and Drug Administration Commissioner, Alexander Schmidt, said, "I'm looking for a clean bill of health, not a wishy-washy, iffy

answer on cyclamates" (14). Senator Edmund Muskie has called for "one-armed" scientists who do not respond "on the one hand, the evidence is so, but on the other hand . . ." when asked about the health effects of pollutants (15). As Gori warns, such demands may tempt scientists to issue "certain" answers which, however convenient for regulators, are unsupportable by science (16).

The search for certainty is legitimate if it is done consciously, if the remaining uncertainties are acknowledged rather than ignored, and if people realize the costs. If a very high level of certainty is sought, those costs are likely to be high. Eliminating the uncertainty may mean eliminating the technology and foregoing its benefits. Often some risk is inevitable. Efforts to eliminate it may only alter its form. We must choose, for example, between the vicissitudes of nature on an unprotected flood plain and the less probable, but potentially more catastrophic, hazards associated with dams and levees.

Analyzing Judgments of Risk

In order to be of assistance in the hazard management process, a theory of perceived risk must explain people's extreme aversion to some hazards, their indifference to others, and the discrepancies between these reactions and experts' recommendations. Why, for example, do some communities react vigorously against locating a liquid natural gas terminal in their vicinity despite the assurances of experts that it is safe? Why do other communities situated on flood plains and earthquake faults or below great dams show little concern for the experts' warnings? Such behavior is doubtless related to how people assess the quantitative characteristics of the hazards they face. The preceding discussion of judgmental processes was designed to illuminate this aspect of perceived risk. The studies reported below broaden the discussion to include more qualitative components of perceived risk. They ask, when people judge the risk inherent in a technology, are they referring only to the (possibly misjudged) number of people it could kill or also to other, more qualitative features of the risk it entails?

Quantifying Perceived Risk

In our first studies, we asked four different groups of people to rate thirty different activities and technologies according to the present risk of death from each (17). Three of these groups were from Eugene, Oregon; they included 30 college students, 40 members of the League of Women Voters (LOWV), and 25 business and professional members of the "Active Club." The fourth group was composed of 15 persons selected nation-wide for their professional involvement in risk assessment. This "expert" group included a geographer, an environmental policy analyst, an economist, a lawyer, a biologist, a biochemist, and a government regulator of hazardous materials.

All these people were asked, for each of the thirty items, "to consider the risk of dying (across all U.S. society as a whole) as a consequence of this activity or technology." In order to make the evalution task easier, each activity appeared on a 3" x 5" card. Respondents were told first to study the items individually, thinking of all the possible ways someone might die from each (e.g., fatalities from non-nuclear electricity were to include deaths resulting from the mining of coal and other energy production activities as well as electrocution;

motor vehicle fatalities were to include collisions with bicycles and pedestrians). Next, they were to order the items from least to most risky and then assign numerical risk values by giving a rating of 10 to the least risky item and making the other ratings accordingly. They were also given additional suggestions, clarifications, and encouragement to do as accurate a job as possible. For example, they were told "A rating of 12 indicates that that item is 1.2 times as risky as the least risky item (i.e., 20 percent more risky). A rating of 200 means that the item is 20 times as risky as the least risky item, to which you assigned a 10 . . ." They were urged to cross-check and adjust their numbers until they believed they were right.

Table 2 shows how the various groups ranked the relative riskiness of these 30 activities and technologies. There were many similarities between the three groups of lay persons. For example, each group believed that motorcycles, other motor vehicles, and handguns were highly risky and that vaccinations, home appliances, power mowers, and football were relatively safe. However, there were strong differences as well. Active Club members viewed pesticides and spray cans as relatively much safer than did the other groups. Nuclear power was rated as highest in risk by the LOWV and student groups, but only eighth by the Active Club. The students viewed contraceptives and food preservatives as riskier and swimming and mountain climbing as safer than did the other lay groups. Experts' judgments of risk differed markedly from the judgments of lay persons. The experts viewed electric power, surgery, swimming, and X-rays as more risky than the other groups, and they judged nuclear power, police work, and mountain climbing to be much less risky.

What Determines Risk Perception?

What do people mean when they say that a particular technology is quite risky? A series of additional studies was conducted to answer this question.

Perceived risk compared to frequency of death. When people judge risk, as in the previous study, are they simply estimating frequency of death? To answer this question, we collected the best available technical estimates of the annual number of deaths from each of the thirty activities included in our study. For some cases, such as commercial aviation and handguns, there is good statistical evidence based on counts of known victims. For other cases, such as the lethal potential of nuclear or fossil-fuel power plants, available estimates are based on uncertain inferences about incompletely understood processes. For still others, such as food coloring, we could find no estimates of annual fatalities.

For the 25 cases for which we found technical estimates for annual frequency of death, we compared these estimates with perceived risk. Results for experts and the LOWV sample are shown in Figure 3 (the results for the other lay groups were quite similar to those from the LOWV sample). The experts' mean judgments were so closely related to the statistical or calculated frequencies that it seems reasonable to conclude that they viewed the risk of an activity or technology as synonymous with its annual fatalities. The risk judgments of lay people, however, showed only a moderate relationship to the annual frequencies of death (18), raising the possibility that, for them, risk

may not be synonymous with fatalities. In particular, the perceived risk from nuclear power was disproportionately high compared to its estimated number of fatalities.

Lay fatality estimates. Perhaps lay people based their risk judgments on annual fatalities but estimated their numbers inaccurately. To test this hypothesis, we asked additional groups of students and LOWV members "to estimate how many people are likely to die in the U. S. in the next year (if the next year is an average year) as a consequence of these thirty activities and technologies." We asked our student and LOWV samples to consider all sources of death associated with these activities.

The mean fatality estimates of LOWV members and students are shown in columns 2 and 3 of Table 3. If lay people really equate risk with annual fatalities, one would expect that their own estimates of annual fatalities, no matter how inaccurate, would be very similar to their judgments of risk. But this was not so. There was a moderate agreement between their annual fatality estimates and their risk judgments, but there were important exceptions. Most notably, nuclear power had the lowest fatality estimate and the highest perceived risk for both LOWV members and students. Overall, lay people's perceptions were no more closely related to their own fatality estimates than they were to the technical estimates (Figure 3).

These results lead us to reject the idea that lay people wanted to equate risk with annual fatality estimates but were inaccurate in doing so. Instead, we are led to believe that lay people incorporate other considerations besides annual fatalities into their concept of risk.

Some other aspects of lay people's fatality estimates are of interest. One is that they were moderately accurate. The relationship between the LOWV members' fatality estimates and the best technical estimates is plotted in Figure 4. The lay estimates showed the same overestimation of those items that cause few fatalities and underestimation of those resulting in the most fatalities that was apparent in Figure 2 for a different collection of hazards. Also as in Figure 2, the moderate overall relationship between lay and technical estimates was marred by specific biases (e.g., the underestimation of fatalities associated with railroads, X-rays, electric power, and smoking).

Disaster potential. The fact that the LOWV members and students assigned very high risk values to nuclear power along with very low estimates of its annual fatality rates is an apparent contradiction. One possible explanation is that LOWV members expected nuclear power to have a low death rate in an average year but considered it to be a high-risk technology because of its potential for disaster.

In order to understand the role played by expectations of disaster in determining lay people's risk judgments, we asked these same respondents to give for each activity and technology a number indicating how many times more deaths would occur if next year were "particularly disastrous" rather than average. The averages of these multipliers are shown in Table 3. For most activities, people saw little potential for disaster. For the LOWV sample all but five of the multipliers were less than 3, and for the student sample all but six were less than 2. The striking exception in both cases is nuclear power, with a geometric mean disaster multiplier in the neighborhood of 100.

For any individual an estimate of the expected number of fatalities in a disastrous year could be obtained by applying the disaster multiplier to the estimated fatalities for an average year. When this was done for nuclear power, almost 40 percent of the respondents expected more than 10,000 fatalities if next year were a disastrous year. More than 25 percent expected 100,000 or more fatalities. These extreme estimates can be contrasted with the Reactor Safety Study's conclusion that the maximum credible nuclear accident, coincident with the most unfavorable combination of weather and population density, would cause only 3,300 prompt fatalities (9). Furthermore, that study estimated the odds against an accident of this magnitude occurring during the next year (assuming 100 operating reactors) to be about 2,000,000:1.

Apparently, disaster potential explains much or all of the discrepancy between the perceived risk and frequency of death values for nuclear power. Yet, because disaster plays only a small role in most of the thirty activities and technlogies we have studied, it provides only a partial explanation of the perceived risk data.

Qualitative characteristics. Are there other determinants of risk perceptions besides frequency estimates? We asked experts, students, LOWV members, and Active Club members to rate the thirty technologies and activities on nine qualitative characteristics that have been hypothesized to be important (19). These ratings scales are described in Table 4.

Mean ratings were quite similar for all four groups. Particularly interesting was the characterization of nuclear power, which had the dubious distinction of scoring at or near the extreme on all of the undesirable characteristics. Its risks were seen as involuntary, delayed, unknown, uncontrollable, unfamiliar, catastrophic, dread, and fatal. This contrasted sharply with the characterizations of non-nuclear electric power and another radiation technology, X-rays. Electric power and X-rays were both judged more voluntary, less certain to be fatal, less catastrophic, less dreaded, more familiar, and less risky than nuclear power (see Figure 5).

Across all 30 hazards, ratings of dread and of the likelihood of a mishap's being fatal were closely related to lay judgments of risk. In fact, the risk judgments of the LOWV and student groups could be predicted almost perfectly from ratings of dread and lethality and the subjective fatality estimates for normal and disastrous years (20). Experts' judgments of risk were not related to any of the nine risk characteristics (21).

Many pairs of risk characteristics tended to be correlated with each other across the 30 activities and technologies. For example, risks faced voluntarily were typically judged well known and controllable. These interrelations were sufficiently high to suggest that all the ratings could be explained in terms of a few basic dimensions of risk. In order to identify such dimensions, we conducted a factor analysis of the correlations from each group (principal components analysis with varimax rotation to simple structure). We found that the nine characteristics could be represented by two underlying factors which appeared to be the same for each group. Figure 6 illustrates the factor scores for each hazard within the common space. Hazards at the high end

of the vertical dimension or factor (e.g., food coloring, pesticides) tended to be new, unknown, involuntary, and delayed in their effects. Hazards at the other extreme of this factor (e.g., mountain climbing, swimming) had the opposite characteristics. High (right-hand) scores on the horizontal factor (e.g., nuclear power, commercial aviation) were associated with events whose consequences were seen as certain to be fatal, often for large numbers of people, should something go wrong. Hazards low on this factor (e.g., power mowers, football) were seen as causing injuries, rather than fatalities, to single individuals. We have labeled the vertical factor as "Unknown Risk" and the horizontal factor as "Dread Risk." In sum, even though the four groups had somewhat different perceptions of the riskiness of the various hazards (Table 2), they tended to characterize these hazards similarly.

Judged seriousness of death. In a further attempt to improve our understanding of perceived risk, we examined the hypothesis that some hazards are feared more than others because the deaths they produce are much "worse" than deaths from other activities. We thought, for example, that deaths from risks imposed involuntarily, from risks not under one's control, or from hazards that are particularly dreaded might be given greater weight in determining people's perceptions of risk.

When we asked students and LOWV members to judge the relative "seriousness" of a death from each of the thirty activities and technologies, however, the differences were slight. The most serious forms of death (from nuclear power and handguns) were judged to be only about two to four times worse than the least serious forms of death (from alcoholic beverages and smoking). Furthermore, across all thirty activities, judged seriousness of death was not closely related to perceived risk of death.

Reconciling Divergent Opinions

Our data show that experts and lay people have quite different perceptions about how risky certain technologies are. It would be comforting to believe that these divergent risk judgments would be responsive to new evidence so that, as information accumulates, perceptions would converge towards one "appropriate" view. Unfortunately, this is not likely to be the case. As noted earlier in our discussion of availability, risk perception is derived in part from fundamental modes of thought that lead people to rely on fallible indicators such as memorability and imaginability.

Furthermore, a great deal of research indicates that people's beliefs change slowly and are extraordinarily persistent in the face of contrary evidence (22). Once formed, initial impressions tend to structure the way that subsequent evidence is interpreted. New evidence appears reliable and informative if it is consistent with one's initial belief; contrary evidence is dismissed as unreliable, erroneous, or unrepresentative. Thus, depending on one's predispositions, intense effort to reduce a hazard may be interpreted to mean either that the risks are great or that the technologists are responsive to the public's concerns. Likewise, opponents of a technology may view minor mishaps as near catastrophes and dismiss the contrary opinions of experts as biased by vested interests.

From a statistical standpoint, convincing people that the catastrophe they fear is extremely unlikely is difficult under the best

conditions. Any mishap could be seen as proof of high risk, whereas demonstrating safety would require a massive amount of evidence (23). Nelkin's case history of a nuclear siting controversy (24) provides a good example of the inability of technical arguments to change opinions. In that debate each side capitalized on technical ambiguities in ways that reinforced its own position.

The Fallibility of Judgment

Our examination of risk perception leads us to the following conclusions:

(1) Cognitive limitations, coupled with the anxieties generated by facing life as a gamble, cause uncertainty to be denied, risks to be distorted, and statements of fact to be believed with unwarranted confidence.

(2) Perceived risk is influenced (and sometimes biased) by the imaginability and memorability of the hazard. People may, therefore, not have valid perceptions even for familiar risks.

(3) Our experts' risk perceptions correspond closely to statistical frequencies of death. Lay people's risk perceptions were based in part upon frequencies of death, but there were some striking discrepancies. It appears that for lay people, the concept of risk includes qualitative aspects such as dread and the likelihood of a mishap's being fatal. Lay people's risk perceptions were also affected by catastrophic potential.

Disagreements about risk should not be expected to evaporate in the presence of "evidence." Definitive evidence, particularly about rare hazards, is difficult to obtain. Weaker information is likely to be interpreted in a way that reinforces existing beliefs.

The significance of these results hinges upon one's acceptance of our assumption that subjective judgments are central to the hazard management process. Our conclusions mean little if one can assume that there are analytical tools which can be used to assess most risks in a mechanical fashion and that all decision makers have perfect information and the know-how to use it properly. These results gain in importance to the extent that one believes, as we do, that expertise involves a large component of judgment, that the facts are not all in (or obtainable) regarding many important hazards, that people are often poorly informed or misinformed, and that they respond not just to numbers but also to qualitative aspects of hazards.

Whatever role judgment plays, its products should be treated with caution. Research not only demonstrates that judgment is fallible, but it shows that the degree of fallibility is often surprisingly great and that faulty beliefs may be held with great confidence.

When it can be shown that even well-informed lay people have difficulty judging risks accurately, it is tempting to conclude that the public should be removed from the hazard-management process. The political ramifications of such a transfer of power to a technical elite are obvious. Indeed, it seems doubtful that such a massive disenfranchisement is feasible in any democratic society.

Furthermore, this transfer of decision-making would seem to be misguided. For one thing, we have no assurance that expert's judgments are immune to biases once they are forced to go beyond their precise knowledge and rely upon their judgment. Although judgmental biases have

most often been demonstrated with lay people, there is evidence that the cognitive functioning of experts is basically like that of everyone else.

In addition, in many if not most cases, effective hazard management requires the cooperation of a large body of lay people. These people must agree to do without some things and accept substitutes for others; they must vote sensibly on ballot measures and for legislators who will serve them as surrogate hazard managers; they must obey safety rules and use the legal system responsibly. Even if the experts were much better judges of risk than lay people, giving experts an exclusive franchise on hazard management would involve substituting short-term efficiency for the long-term effort needed to create an informed citizenry.

For those of us who are not experts, these findings pose an important series of challenges: to be better informed, to rely less on unexamined or unsupported judgments, to be aware of the qualitative aspects that strongly condition risk judgments, and to be open to new evidence that may alter our current risk perceptions.

For the experts, our findings pose what may be a more difficult challange: to recognize their own cognitive limitations, to temper their assessments of risk with the important qualitative aspects of risk that influence the responses of lay people, and somehow to create ways in which these considerations can find expression in hazard management without, in the process, creating more heat than light.

References and Notes

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Acknowledgment

The authors wish to express their appreciation to Christoph Hohenemser, Roger Kasperson, and Robert Kates for their many helpful comments and suggestions. This work was supported by the National Science Foundation under Grant ENV77-15332 to Perceptronics, Inc. Any opinions, findings and conclusions, or recommendations expressed herein are those of the authors and do not necessarily reflect the views of the National Science Foundation.

Table 1. Bias in Judged Frequency of Death

Most Overestimated	Most Underestimated
All accidents	Smallpox vaccination
Motor vehicle accidents	Diabetes
Pregnancy, childbirth, and abortion	Stomach cancer
Tornadoes	Lightening
Flood	Stroke
Botulism	Tuberculosis
All cancer	Asthma
Fire and flames	Emphysema
Venemous bite or sting	
Homicide	

Table 2. Ordering of Perceived Risk for 30 Activities and Technologies

	Group 1 LOWV	Group 2 College Students	Group 3 Active Club	Group 4 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	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

a The ordering is based on the gemoetric mean risk rating within each group. Rank 1 represents the most risky activity or technology.

Table 3. Fatality Estimates and Disaster Multipliers for 30 Activities and Technologies

Activity or Technology	Technical Fatality Estimates	Geometric Mean Fatality Estimates Average Year		Geometric Mean Multiplier Disastrous Year	
		LOWV	Students	LOWV	Students
Smoking	150,000	6,900	2,400	1.9	2.0
Alcoholic beverages	100,000	12,000	2,600	1.9	1.4
Motor vehicles	50,000	28,000	10,500	1.6	1.8
Handguns	17,000	3,000	1,900	2.6	2.0
Electric power	14,000	660	500	1.9	2.4
Motorcycles	3,000	1,600	1,600	1.8	1.6
Swimming	3,000	930	370	1.6	1.7
Surgery	2,800	2,500	900	1.5	1.6
X-rays	2,300	90	40	2.7	1.6
Railroads	1,950	190	210	3.2	1.6
General (private) aviation	1,300	550	650	2.8	2.0
Large construction	1,000	400	370	2.1	1.4
Bicycles	1,000	910	420	1.8	1.4
Hunting	800	380	410	1.8	1.7
Home appliances	200	200	240	1.6	1.3
Fire fighting	195	220	390	2.3	2.2
Police work	160	460	390	2.1	1.9
Contraceptives	150	180	120	2.1	1.4
Commercial aviation	130	280	650	3.0	1.8
Nuclear power	100[a]	20	27	107.1	87.6
Mountain climbing	30	50	70	1.9	1.4
Power mowers	24	40	33	1.6	1.3
High school & college football	23	39	40	1.9	1.4
Skiing	18	55	72	1.9	1.6
Vaccinations	10	65	52	2.1	1.6
Food coloring	--[b]	38	33	3.5	1.4
Food preservatives	--[b]	61	63	3.9	1.7
Pesticides	--[b]	140	84	9.3	2.4
Prescription antibiotics	--[b]	160	290	2.3	1.6
Spray cans	--[b]	56	38	3.7	2.4

a Technical estimates for nuclear power were found to range between 16 and 600 annual fatalities. The geometric mean of these estimates was used here.

b Estimates were unavailable.

Table 4. Risk characteristics rated by LOWV members, Active Club members, students, and experts.

Voluntariness of risk

Do people face this risk voluntarily? If some of the risks are voluntarily undertaken and some are not, mark an appropriate spot towards the center of the scale.

risk assumed voluntarily	1	2	3	4	5	6	7	risk assumed involuntarily

Immediacy of effect

To what extent is the risk of death immediate--or is death likely to occur at some later time?

effect immediate	1	2	3	4	5	6	7	effect delayed

Knowledge about risk

To what extent are the risks known precisely by the persons who are exposed to those risks?

risk level known precisely	1	2	3	4	5	6	7	risk level not known

To what extent are the risks known to science?

risk level known precisely	1	2	3	4	5	6	7	risk level not known

Control over risk

If you are exposed to the risk, to what extent can you, by personal skill or diligence, avoid death?

personal risk can't be controlled	1	2	3	4	5	6	7	personal risk can be controlled

Newness

Is this risk new and novel or old and familiar?

new	1	2	3	4	5	6	7	old

Chronic/Catastrophic

Is this a risk that people have learned to live with and can think about reasonably calmly, or is it one that people have great dread for--on the level of a gut reaction?

common	1	2	3	4	5	6	7	dread

Severity of consequences

When the risk from the activity is realized in the form of a mishap or illness, how likely is it that the consequence will be fatal?

certain not to be fatal	1	2	3	4	5	6	7	certain to be fatal

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