General Safety Considerations

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The Nuclear Community and the Public: Cognitive and Cultural Influences on Thinking About Nuclear Risk

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Abstract: *This article examines why the public holds views of nuclear-related risk different from people working in the field of nuclear safety. In particular, the study looks at how feelings enter into thinking about risk. It focuses on (1) the nuclear community, specifically the technical experts who perform accident analyses, and the regulators who use these analyses in making risk assessments or policy decisions; and (2) the general public. This article summarizes these groups' approaches to nuclear risk and explores the effects of cognition and cultural conditioning in creating these differences. The goal is to increase the nuclear community's understanding of the public's approach to risk, as well as its own, in hopes of improving communication.*

This article is a summary of literature gathered from diverse fields describing how people think and feel about nuclear-related risks. Its aim is to help the nuclear community, especially the U.S. Nuclear Regulatory Commission (NRC) and its contractors, understand how they differ from the public in thinking about such risks.

The intended audience includes the scientists and engineers who work in the area of nuclear safety. They may be technical experts, such as the scientists who perform accident analyses by creating and running complex computer models, or they may be regulators, the decision makers who use these analyses in making risk assessments or policy decisions. The article describes the cognitive and cultural influences that selectively operate to form their views of nuclear risk; however, this study is expected to benefit any member of the nuclear community who communicates with the public about nuclear safety.

Understanding how the public thinks about nuclear risk is important for several reasons. First, nuclear engineers and scientists often have dealings with the public concerning nuclear safety; for instance, the NRC personnel frequently communicate with the public, such as in circulating rules and environmental assessments for review, responding to petitions and allegations, holding open meetings, sponsoring workshops on controversial issues, and answering general questions about nuclear energy and radiation issues. Understanding people's thinking about risk has been identified as necessary to communicating effectively about risk and to creating acceptable public policy.[1,2]

Second, communications with the public on nuclear risk have been problematic; for example, the NRC has encountered difficulties in communicating information

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to the public; the NRC provides information when individuals ask or when the regulations stipulate (e.g., when environmental assessments are to be disseminated for review). The purpose of the NRC's informational program is to explain the technology, to articulate its risk with precision, and to let people evaluate for themselves the technology's acceptability;[3] however, many times the public does not want to hear the "facts" about nuclear energy, nor do they believe the NRC's assessments of risk. In one well-known instance, H. Denton, the NRC's chief official on site after the Three Mile Island (TMI) accident, could not convince a portion of the public that the radioactive release had been very small—a fraction of the agency's regulatory limit. These individuals would not believe the NRC records of the release. Because they had metallic tastes in their mouths, they were convinced that there had been a massive release.[4]

The work described here began as an attempt to answer some questions concerning people's thinking about risk:

- Why has informing the public about the scientific basis of risk assessments had so little effect on the public's views in the last few decades?
- How do feelings enter into thinking about risk?
- In particular, why are the public's feelings about nuclear risk so resistant to change or scientific counterargument?
- More generally, why do technical experts view risk so differently from the public?

This article offers answers to these questions. It differs from other reviews of the risk literature in three ways: (1) it includes findings from more diverse fields, such as physiology and anthropology; (2) it examines the role of people's emotions in their thinking about risk; and (3) it proposes the cognitive mechanisms by which individuals become aware of risk and deal with it. In general, this article proceeds from describing how different groups evaluate risk to explaining why these differences exist.

Specifically, the article is organized as follows: (1) a description of how the public and the technical experts/regulators approach risk, including recent findings on the public's feelings about nuclear-related risks; (2) an illustration of the physiological, emotional, and cognitive mechanisms involved in the individual's response to risk; (3) a culturally based explanation for the differences in the technical experts' and public's views of nuclear risks; and (4) a summary.

THE PUBLIC EVALUATES NUCLEAR-RELATED RISKS DIFFERENTLY THAN EXPERTS OR REGULATORS DO

To describe the views of risk of different groups, risk must first be defined. Risk is the "potential for realization of unwanted, negative consequences."[5] Negative consequences can range from relative intangibles, such as decreased quality of life (e.g., as the result of mental anguish), to more concrete possibilities, such as the loss of health, life, or property; for instance, making a left turn across traffic could be viewed as risking frustration, loss of time, vehicle damage, injury, or even death.

The Public's Approach to Risk

The public is defined here to mean the diverse groups of citizens, some of whom may belong to special interest groups, such as the Sierra Club. This population is frequently studied by means of random telephone or mail surveys. According to such surveys, the public's approach to risk tends to be qualitative, anecdotal, and personal. Typically, the public thinks about risk in terms of their feelings and of the effects of the risks on themselves and their loved ones.[6]

The following additional characteristics of people's thinking are likely to impact their evaluation of nuclear-related risks.

Individuals mentally lump the risks from nuclear weapons and nuclear waste with those of nuclear power reactors. Evidence that lay people mentally lump all nuclear risks can be found in Slovic's study of risk perception.[7] In this study, people ranked nuclear reactor accidents next to nuclear weapons' fallout in their perception of the riskiness of these hazards.

Additional evidence that people lump nuclear risks comes from psychological studies of images. These studies are based on the concept that people's cognitive images are accompanied by feelings and that such images have important behavioral consequences. In particular, people's images of a city predict their preferences for vacationing or relocating there;[8] for instance, an image of a sunny beach and azure water is likely to encourage tourists, especially in the winter.

In studies of images, people are given a word or phrase such as "reactor accident" and asked for the words they associate with it. In three separate studies of the images associated with reactor accidents, nuclear waste repositories, and nuclear war, people's images of disaster were equivalent. In particular, the

people's images of the consequences of reactor accidents were the same as those that they gave for nuclear war. [9]

Slovic[8] offers an explanation of why people's perceptions of reactor accidents are so severe when there have been relatively few fatalities to date. He notes that the early reactor risk assessments were worst-case scenarios causing tens of thousands of deaths and that these received much publicity, such as in the movie "China Syndrome."

Individuals implicitly think about many factors in considering riskiness. Experimental psychologists Slovic, Lichtenstein, and Fischhoff have studied people's perceptions by asking them to rank the risks of well-known hazards (e.g., numerically rate the riskiness of these hazards and the level of regulation they desired for each). They also asked people to rate the hazards with regard to characteristics thought to be important for the way people perceive risk.

Their results[7] showed that people's views of risk tended to differ from their own and experts' estimates of annual fatalities. [a] People rank risks on the basis of such characteristics as how well they understand the problem, how equitably they feel the danger is distributed, how well they can control their exposure, whether they have assumed the risk voluntarily, and how children and future generations are affected by the risks.

Individuals view nuclear hazards as riskier. When several of the characteristics associated with riskiness are grouped, nuclear power is one of the highest scoring hazards. Slovic[7] used psychophysical scaling and multivariate analyses to group the following characteristics: "perceived lack of control, dread, catastrophic potential, fatal consequences, and the inequitable distribution of risks and benefits." The higher a hazard's score in this grouping, the higher the perceived risk, the more that people want its risks reduced, and the more they want strict regulation. Nuclear weapons and nuclear power score highest on these characteristics of riskiness. People's perceptions of the riskiness of nuclear power do not change when they consider its parts—radioactive waste, uranium mining, and nuclear reactor accidents. According to Slovic,[7] these results have been replicated in studies across a wide cross section of the population.

[a]According to Slovic,[7] experts' views of risk correlate highly with technical estimates of annual fatalities.

Analysis of nuclear imagery reveals negative images indicative of feelings of revulsion and fear. In their study of the images of nuclear waste repositories, Slovic, Layman, and Flynn[8] found extremely negative images of "dangerous/toxic," "death/sickness," "environmental damage," and "bad and scary." Positive images, such as of "employment" or "money/income," accounted for only a few percent of the images. These images were relatively stable across time (1988 to 1990) and populations (the nation at large and residents of Nevada, Arizona, and California).

The researchers compared these images with those in other studies and concluded that the feelings that underlie these images are of "dread, revulsion, and anger; the raw materials of stigmatization and political opposition." Given that people lump nuclear risks together, this conclusion can be viewed as applying to nuclear reactor accidents also.

Revulsion or fear may not be amenable to logical thinking, even in those aware of this effect. Information on how people act when experiencing revulsion comes from studies of averse reactions.[10] In such studies, college students were asked what they would do in the following situations: drink their favorite juice if a dead cockroach was dipped in and removed; if a dead and sterilized cockroach was dipped in and removed; or if a brand new fly swatter was used to stir it. In these three situations, approximately the same number of students said they would not drink their juice; however, only in the first instance, the dead cockroach, could fear of exposure to germs be the reason for revulsion and refusal. In the last two cases, the students knew that they were being irrational; however, this did not change their feeling of revulsion nor their reluctance to drink a contaminated beverage.

This same kind of reaction occurs in other situations where there is even less chance of contagion; for example, college students are reluctant to wear a sweater that has been sterilized after being worn by a person who has committed moral offenses, such as child molestation. The students know that their feelings and behavior are irrational, but they are unable to do otherwise.

Redelmeier, a physician,[10] states that averse reactions, such as revulsion, can be resistant to change, even if people know that these feelings are irrational and even if they have been given scientific counterarguments. He further proposes that people do not usually volunteer information on averse emotions and may not even be aware that they have

them. This effect is of special interest given the previous evidence of many people's aversion to nuclear technologies.

People's evaluations of nuclear risk may be influenced by their trust in the managing organizations. Although the evaluation of nuclear risks by people may not be affected by logic, it may be influenced by trust. A study was done of Nevadans' views of the nuclear waste repository project.[11] Multivariate analysis showed that perceptions of economic benefits were not good predictors of opposition to the project but that risk perceptions and trust in repository management were closely linked to the positions of people on the project. The trust of people directly influenced their risk perceptions; this, in turn, had a direct effect on their view of the repository. In other words, the confidence of people in the managers of a technology influenced their perception of a technological risk and the position that they took on it.

The authors of *Public Reaction to Nuclear Waste*[12] confirm the importance of trust to the perception of risk and add that public trust in American institutions has been declining for the last 30 years. They note that no new reactors have been built since the late 1970s and that surveys indicate that the majority of Americans are against building new ones. Along these lines, E. Beckjord, the former Director of the NRC's Office of Nuclear Regulatory Research, has stated that public "confidence in the assurances given by the technical experts that nuclear energy was 'safe' was severely shaken" by the TMI event.[13]

Technical Experts and Regulators' Approach to Risk

Technical experts and regulators, in contrast to the public, take a quantitative and abstract view of risk; for example, risk analysis focuses on identifying the hazards and the means by which people would be exposed; for instance, with respect to reactors, technical experts use computer codes to model the paths by which reactor accidents could occur, the probabilities of their occurrence per year, and their consequences.[14] In fact, probabilistic risk analysts define risk in mathematical terms as the expected number of occurrences (frequency) times the consequences for that occurrence. Consequences are usually figured in terms of human lives lost and health effects as the result of exposure to radiation. Radiation exposure is quantified by determining the amount of radiation received as measured in rems. Regulators, such as those in the NRC, then use the results of these risk assessments in making policy decisions. In instances where safety has been found to be adequate and improvements are being considered, then cost–benefit analyses may also be performed. In cost–benefit analyses, the costs and benefits for reducing a risk, such as by implementing a safety feature, are quantified (e.g., in the number of workdays and money lost or gained).

In summary, the technical experts and regulators describe risk in a language of technical detail, quantities, and generalized costs–benefits.[1,6]

The Result—Adversarial Relations in Risk Regulation

That technical experts and regulators evaluate risk differently than the public is especially evident in the regulatory arena. Risk assessors, managers, and regulators are very aware that the public does not share their views of risk. Morgan summarizes their view:

> Many advocates, such as industry representatives promoting unpopular technology or Environmental Protection Agency staffers defending its regulatory agenda, argue that the public has a bad sense of perspective. Americans, they say, demand that enormous efforts be directed at small but scary sounding risks while virtually ignoring larger, more commonplace ones.[1]

Otway,[15] a noted international risk analyst, has characterized the approach to risk regulation in the United States as adversarial: "Regulations are developed in open confrontation, often with resort to the legal system to settle disagreements." Rowe, another risk analyst, confirms Otway's view and elaborates on this process: issues that are unacceptable to some groups are "blown up through dire predictions of consequences, based primarily on half truths, but flamed by competing commercial news media."[5] The goal is to stir public opinion so as to affect governmental representatives, consumer regulatory agencies, and the courts.

This confrontational approach seems especially true of interactions on nuclear power and radioactive waste disposal. "Decisions that formerly were exercised by scientists, technology managers, and public officials are now subject to extensive public

debate, and in many cases decisions are reversed because of the public."[11,13] Two examples of the effect of public opposition are the decline in nuclear power plant construction and the delay in the siting of the nation's first high-level nuclear waste repository.

According to Otway,[15] technical experts have been surprised by the increasingly confrontational atmosphere, especially by the "lay challenges to their informed expert judgment." As scientists they had believed that regulatory decisions would be less controversial if their basis in science could be established.

This situation has been the case in the probabilistic risk and safety assessments (PRAs and PSAs) performed on nuclear power reactors. Analysts in this field have believed, albeit for different reasons, that the scientific foundations of their work have become more established in recent years; for example, some of the analysts view their field as a tool for presenting the objective truth. To illustrate, Morgan notes that the maturing of the risk analysis field has made it "possible to examine potential hazards in a rigorous, quantitative fashion and thus to give people . . . facts on which to base essential personal and political decisions."[1]

Others performing PRAs or PSAs propose that the probabilistic assessments are tools for measuring experts' degree of belief.[16] Of these, Watson has argued that risk analysis should provide "a rational framework for the debate about safety. . . . The argument about safety should be on the adequacy of the model, the nature of the expert judgment, the quality of the computer codes, and so on."[17] However, neither groups' claims to the rational or scientific basis of their assessments seem to have affected the public's views.

Why then does this adversarial situation exist and seem to be worsening? More basically, why do the technical experts and regulators view risk as they do and so differently than the public does? Why has informing the public about the scientific basis of risk assessments failed to change the public's views? How do feelings enter into thinking about risk? In particular, why are the public's feelings about nuclear risk so resistant to change or scientific counterargument?

To address these questions requires an understanding of how people think about risk. This article next describes the physiological mechanisms involved in thinking about risk.

PHYSIOLOGICAL, EMOTIONAL, AND COGNITIVE MECHANISMS INVOLVED IN THINKING ABOUT RISK

Physiological Mechanisms Involved in Responding to Imminent Risk

The physiological responses to danger form the foundations of our thinking about risk. Physiological mechanisms are the neurological and biochemical processes that allow us to quickly assess imminent danger and respond (e.g., fight or flight). The latest information on how these mechanisms work comes from studies of the fear response—the reactions of animals facing threatening situations (e.g., their muscles contract, they startle easily, and their blood pressure and heart rate increase).

One important finding has been that the fear response relies on crude cognitive information processing.[18] Take, for example, a hiker hearing a rustling sound and seeing a coiled slender form on the path ahead. The stimulus from the auditory system (hearing a rustling sound) or the visual system (seeing a coiled slender shape) is processed by the thalamus and passed to the amygdala as a possible danger—snake—that then causes the heart rate and blood pressure to increase and muscles to contract in less than a second. LeDoux believes that the fear response is "quick and dirty" for a reason—evolutionary adaptation. He argues that it is an evolutionary adaptation because (1) it is fast and therefore potentially life saving; and (2) failing to respond would be more costly to survival than responding inappropriately to something benign.

Another of LeDoux's findings is that the fear response results in relatively permanent emotional memories. Emotional memory is our access to the consequences (the way that we feel and the way that we behave) of an unconscious emotional process; for example, if we were in a car accident, we would remember our feeling of panic, our body tensing for the impact, and so on. It has been shown that the "amygdala (a small almond-shaped body in the center of the brain) plays an essential part in modulating the storage and strength of memories."[18] Thus fearful responses are learned quickly but are not, correspondingly, forgotten quickly. Indeed, LeDoux argues that emotional memories are not erased, but rather, fearful behaviors are controlled by the part of the brain responsible for more sophisticated information processing—the cortex.

LeDoux's findings may be important to understanding human response to risk. His work indicates that responding to danger is a physical and cognitive priority—that our history as a species may favor a quick and extreme reaction to any perceived risk. The fear response may explain, in part, why people react more strongly to the potential hazards of a new technology than to its benefits and why once fear has been aroused, it is slow to subside.

A third characteristic of the fear response is that emotional memory and the memory of "things" combine seamlessly in our conscious experiences.[18] (The learning of things is mediated by a separate system from emotional learning.) Thus we can simultaneously recall both the details, such as where and how an accident happened, and the emotional memories of how it felt. Similarly, in thinking about the details, we may reexperience the same emotions, fear, and anxiety that we had at the accident scene.

This interplay of emotional and nonemotional memories is relevant to other situations beyond the fear response; namely, everyday life. Our feelings influence our thoughts and actions;[19] and our thoughts, in turn, can determine our emotional states (e.g., imagining the worst can cause frustration).[20] How our emotions and thoughts intertwine when we consider risk will be discussed in detail in the following text.

Cognitive Aspects Involved in Anticipated Risks

The emphasis from here on will be on future risks rather than on immediate dangers because those are what people anticipate when they consider the risks posed by technological change. In general, people spend more time worrying about risks than responding to immediate threats.

Two aspects of anticipation of risk are of interest here: feeling-based thinking and intuitive modeling. Feeling-based thinking occurs when people are thinking of a feeling, such as an emotion like anxiety, or a physical feature like tightness in their gut. Thinking is involved because the individual must interpret what is felt and what this feeling means; for example, an individual might think to himself, "Is this tight feeling in my gut from hunger or uneasiness? If I'm uneasy, why am I uneasy, and what can I do about it?" (Modeling, the means by which the individual thinks about such things, will be discussed separately in the section on Characteristics of Modeling.)

Feeling-based thinking can be viewed as a more complex version of the emotional mechanisms of the fear response. As LeDoux proposes,[18] people's experiencing of feelings arises from the system that forms the basis of the fear response. With the fear response, thought processes have to be quick and dirty; with anticipating risk, however, there is time to deliberate. Thus thinking about future risk allows more complex information processing (such as involving the cortex of the brain) and interpretation. New research on memory clearly links the emotional mechanisms of the fear response to everyday living.[21] This research shows that memory is boosted by everyday emotions, such as being worried or a little scared. Our emotional memory seems to work in graduations, activated in proportion to the emotional charge.[22]

Proposed Characteristics of Feeling-Based Thinking

Feelings are used to evaluate corporal, emotional, or ethical states. People typically employ this kind of thinking to check their corporal, emotional, or ethical feelings in a projected situation; for example, a person may mentally ask himself "Would I feel good about that?" and check his body for a feeling of tightness or discomfort.[23] In this way, feeling-based thinking gives quick feedback to the individual about contemplated decisions or actions.

Feelings are likely to enter into decisions about the acceptability of risks. Because feeling-based thinking is used by individuals to assess their feelings about situations, it naturally enters into decisions about values—"what do I desire or what do I consider good?" The social acceptability of risks has recently been defined as a question of values rather than of facts.[1,5,6] Thus feeling-based thinking could play heavily in the arena of people's perceptions of the acceptability of risks.

Feelings are trusted more than reasoning in decision making. People are in the habit of using feeling-based thinking to mentally check projected situations; so they are comfortable with this process and trust it. Indeed, people often believe that their feelings provide them with a deeper truth or with a more reliable guide for decision making than reason;[23] for instance, Ann Landers advises her readers to follow their guts. "I'm a great believer in trusting one's gut. My own has never failed me. What one feels is often more important than what one thinks."[24]

Even risk analysts are not exempt from following their guts; for example, Lewis, a risk consultant for

50 years, said that he had trouble using seat belts in cars. "He would never fly a plane without fastening up, but felt that the seat belt in his car was an intrusion on his free will. He says it was perfectly normal and yet irrational."[25]

Feelings carry the same convincingness as do the emotional memories from fear responses. The primacy of feeling-based thinking partially explains why people's feelings about risk are not responsive to logic, especially others' logic.

What is felt is taken for reality. Evidence that people believe what they feel comes from studies of their perceptions. Samuelson notes that the real dangers of daily life are low and decreasing (e.g., as shown by statistics on crime and on health, safety, and environmental hazards), whereas our fears are "high and rising." He attributes this phenomena to our being inundated by psycho-facts:

> beliefs that, though not supported by hard evidence, are taken as real because their constant repetition changes the way we experience life. We feel assaulted by rising crime, increasing health hazards, falling living standards and a worsening environment. . . . The underlying conditions aren't true, but we feel they are and, therefore, they become so.[26]

One reason why psycho-facts affect our feelings and subsequent perceptions of reality is emotional memory. As Cahill's research showed,[21] we selectively remember the news that upsets us. This means that the public is likely to forget the neutral information on a much publicized technology, like nuclear power, and to remember only the news that worried them. Over time, it is possible that some people may develop an aversion to a technology, where just thinking about it makes them feel revulsion. This revulsion toward nuclear technologies has been documented among many populations, as was described earlier in the section on nuclear images.

Feelings play a special role in alerting people to risk and letting them know when they have dealt with it. Although people's dealings with risk involve visual, aural,[a] and feeling-based thinking, the feelings are likely to be key. In particular, feelings are the means by which individuals become aware of risk. This process will be described in detail in the section on Interaction Between Feelings and Modeling.

Characteristics of Modeling

In addition to feeling-based thinking, individuals use mental models in dealing with risk. Models are defined as "selective abstractions that help users identify, explain, predict, and control events in the world."[28] Given this definition, worry is one form of modeling;[b] for example, when we worry, we

> create scenarios or images of impending events based in part upon what we feel is fairly certain in our future and in part on vague notions of what we believe is possible (rather than probable). Such scenarios could serve as means for understanding ways in which future events might be realized and could be useful in preparing to meet them.[29]

Models are created in interaction with the situation. The models that the individual creates are done so in interaction with the situation.[30] The situation broadly includes the things in time and the environment that are associated with the risk—for instance, the person's concept of self (e.g., what he thinks he can or should do), past experiences (e.g., factual and emotional memories), and other cultural factors.

Note that individuals may create more than one model per situation, and these models may be logically inconsistent. Take, for example, someone who is worrying. The individual "may create a spectrum of potential scenarios, some of which may be mutually exclusive, and proceed to worry simultaneously about the outcome of each. . . ."[31]

Models include assumptions about how things function. Individuals' models include implicit assumptions about how things in the world function or are related, especially causally. Individuals use their understanding to try to control outcomes, in this case, to avoid the negative consequences of risk.

Take, for example, the area of risk to health. In one woman's model, becoming chilled was the cause of head colds. She stated that she and two members of her family came down with bad head colds this summer because they had become chilled by the extreme air

[a]In addition to thinking by means of feelings, people can mentally think in terms of pictures or sounds.[27] Each of these ways of thinking has its own flavor. Visual thinking has the nuance of viewing something from a distance, such as when one replays where one has been to find a lost object. Aural thinking has the flavor of mentally monitoring one's place in a process (e.g., "I've done this and this and need to do that next") or of cautioning ("this situation could backfire") or criticizing oneself and others.

[b]Note that the running of computer codes for assessing technological risks and this report's description of human thinking about risk can be viewed as other forms of modeling; they are external manifestations of the human capacity to mentally model.

conditioning in church. Her implicit model was that exposure to cold temperatures, not germs, caused the head cold. At a more detailed personal level, she believed that head colds caused her to have subsequent earaches, chest colds, and laryngitis.

Models imply a course of action. Individuals employ their models in thinking about how to achieve something desired or to avoid an unwanted consequence. Thus, in the preceding example, the woman's model led her to dress warmly year round to avoid getting a cold.

Models behave like reality in the expectations of their users. Compton et al. point out that a "basic feature of a model is that it can simulate reality, behave like reality according to the expectations of the users. . . . The model is not the thing but it behaves like the thing, not in an absolute sense but according to the expectations of the. . . users;"[32] for instance, in the head cold example, the woman acts as if her model were reality. She follows the implied course of action in the belief that it will save her from getting a bad ear infection. She does not consider her thinking as a model, an abstraction, or a simplification of reality.

Models are often based on illusory correlation. The assumptions in the individuals' models are often wrong because humans and other animals frequently assume that things covary, when, in fact, they may not.[33,34] This tendency is called illusory correlation. Illusory correlation stems from a very basic tendency—to mentally associate events that occur together in time.

This process of linking events has allowed creatures through time to learn causes and effects and to manipulate them; for example, pigeons will associate random feedings with whatever motion (e.g., hopping) they were making just before the food arrived. Baseball pitchers will associate the onset of a losing streak with some unrelated object, such as an unlucky hat, and will subsequently avoid it as taboo.[35] The tendency to link events and assume causal relationships is the basis for animal training, fear conditioning, and the creation of rituals or taboos;[35] however, this process often leads to incorrect assumptions about how things are related. Thus, in modeling, the individual is often mistaken about what causes a particular loss and how to avoid it in the future.

Models are updated. The person's models change in interaction with situations; for example, the woman who believed that cold temperatures caused her to get head colds had learned this from her mother. Her mother had provided her with a background of what caused head colds—exposure to cold. Her mother also said that going from extreme hot to cold temperatures caused bladder infections; however, the daughter changed her submodel as a result of a situational experience: "I learned my mother was wrong when I was in Florida because we went from very hot to very cold in the Pizza Hut. The cold made my bones ache, like they feel before you get the flu, but I never got a bladder infection."

For models to evolve, they need to be replaced by better models (that is, models that are less wrong). Models are described as less wrong rather than right because all models are simplifications and therefore, even at best, cannot be correct.[a] Thus, for models to evolve, they must be recognized as wrong and replaced with something less wrong.

Models do not always evolve, however. Sometimes they are replaced by models that are more wrong, such as when a person overgeneralizes from some traumatic experience (e.g., when a person concludes that cars cause death). More commonly, though, people's models are slow to change; for example, it has been noted that people's illusory correlations "can persist in the face of disconfirming evidence."[33]

Interaction Between Feelings and Modeling

This section illustrates how modeling and feeling-based thinking might interact in situations involving risk.

Feelings alert individuals to the presence of risk. Feeling-based thinking is the cue that alerts individuals to an anticipated risk; for example, in thinking about an upcoming situation, such as a tax audit or voluntary surgery, the person's emotion could be fear, anxiety, worry, or dread; his feelings could be vague uneasiness or physical symptoms, like a queasy stomach, tight chest, racing heart, or sweaty palms. Generally, the feelings that alert the individual to risk will be those judged unpleasant or negative.

After the negative feelings have alerted the individual to risk, the individual begins modeling the situation. After the negative feelings have alerted the individual to the possibility of loss, the individual starts thinking about the situation, modeling it as described

[a]In addition, models cannot be proven correct, only wrong. According to the philosopher Popper,[30] models are like hypotheses, and hypotheses can never be proven true—only false.

in the preceding section. Modeling is part of the individual's response to the risk; it allows the individual to relate aspects of the situation to the outcome. Generally, individuals will try to change either the anticipated undesirable consequences, their negative feelings, or both.

One means of changing the consequences is to take action to limit them. The options for action are typically implied by the individual's model; for instance, the woman in the earlier example was alerted to the risk of an ear infection by her cold symptoms. Her model predicted that colds lead to ear infections unless she kept her ears free of fluids. Thus she took action—decongestants—to keep her colds from spreading to her ears.

One means of changing the negative feeling is to deny it; for instance, the woman could have denied that she had a cold, thinking, for example, "I don't have a cold because I can't afford to be sick now. Maybe it's just allergies." Other means of changing the negative feeling are by taking drugs, exercising, praying, meditating, or engaging in relaxation techniques. Note that the individual can employ a variety of strategies in changing the consequences or the negative feelings and that these are likely to overlap.

Feelings are the means by which individuals judge that they have resolved the risk. Feeling-based thinking is the means by which individuals know that they have resolved the imagined or actual situation, that their efforts have worked, and that they can go on to something else. The kinesthetic feedback that allows them to go on is typically a positive feeling of confidence, an "it's-going-to-be-all-right mood," a relaxed state, or an "at-peace" sensation. Individuals may check their feelings as a conscious judgment, such as when they decide that they will keep thinking of solutions until they find one with which they are comfortable, or people may be unaware that they are using their feelings in this manner until it is called to their attention.

If people do not receive positive feelings as feedback, they may become stuck in the unpleasant state of uneasiness, or worse, fear. In the extreme case, this most often occurs after the individual has been a victim of some traumatic experience. No matter what coping strategies the individual employs, his mental check just reveals muscular tension and fear. Owing to the relative permanence of emotional memories from a fear response, this situation may continue for a long time.

For example, a woman who had been in a car accident reduced her amount of driving and avoided busy thoroughfares; however, these strategies did not help greatly:

> When a "car follows too closely, her heart races. She locks her jaw and tenses her muscles." . . . She has flashbacks to the accident in April that totaled her Mitsubishi Mirage. She's afraid to drive. "I feel like that impact is going to come again," . . . . "I just want to get into a car and drive without worrying."[36]

More commonly, however, individuals become stuck in receiving slightly negative feelings as feedback over a shorter period of time. This often occurs when they are trying to make a difficult decision and none of the alternatives are totally satisfactory. Negative consequences or risks are associated with each option. The individual knows that he is not happy with the status quo (this is the negative feedback) and thinks of alternatives but is not comfortable with these either (this is also negative feedback).

CULTURAL FACTORS AFFECTING APPROACHES TO RISK

Cultural factors condition how people perceive and react to risk. Culture is simply defined as what people learn socially as members of groups. Groups include family, religious, educational, vocational, and interest groups. People learn beliefs, values (e.g., what is good), and norms for behavior (when is it appropriate to act a certain way). The learning can be conscious, such as through receiving instruction, or unconscious, such as by emulating others. Through this process, people internalize the group's culture; that is, they adopt many of its beliefs, values, or norms as their own. As a result, they are likely to view things from their culture's perspective and to perceive its ways as superior.[37] This tendency—ethnocentrism—operates in the risk arena and accentuates the differences between groups.

People Learn Mental Models, Emotions, and What Is Considered Risky from Their Cultures

People learn models. Individuals learn their culture's beliefs on how objects in the world are related. These beliefs are, in essence, models; for instance, members of western scientific culture believe that colds are caused by germs and that these are

transmitted to others via their nose, eyes, or mouth. Thus members of this culture believe that sharing silverware with a cold sufferer is risky behavior.

These models are viewed as indisputable by the members of a culture; for example, just as many in the Western scientific world consider germs to be the root explanation of illness, many in Africa (even those trained in Western medicine[38]) believe witchcraft to be the underlying cause. To each, his own model is truth; the other's model is wrong, naive, or nonsensical. This kind of thinking illustrates the effect of ethnocentrism.

People learn when and how to feel and express emotions. Individuals learn what is valued, and this sets a context for the experiencing of emotions; for example, members of Western society tend to value sanitary conditions as *good*, and given their belief in the germ model, *healthy*. Thus members of this culture are likely to feel revulsion at the thought of flies climbing on their food or faces.

Individuals also learn the context in which an emotion is felt and expressed; for example, what makes a person angry depends upon those situations or events which are considered by his culture offensive or frustrating.[39] For instance, the Mescalero Apache Tribal President has proposed to open a monitored retrieval storage facility for spent nuclear fuel rods on the reservation in New Mexico.[40] Angry antinuclear activists have chanted protests outside the reservation. These protesters were not members of the tribe. Tribal members may not have felt angered by their tribal leader's proposal, or they may not have considered it appropriate to express their anger overtly.[a]

Note that individuals are sometimes trapped in feeling their own emotions. They may wish to feel otherwise but be unable to do so because they have learned emotions in a single-minded way;[34] for example, they may have learned that snakes are frightening or that "no nukes are good nukes." They have become victims of their own mental associations.

[a]In January, Mescalero Apache tribal members voted 490 to 362 against the creation of the storage facility. The tribe's manager for the project attributed the loss to "fear of possible contamination by the fuel rods and to ignorance about the project."[41] Six weeks later, the tribe voted in favor of the storage facility.[42]

Scientists Belong to a Separate Subculture and Are Socialized Differently Regarding Risk

As a result of their educations and on-the-job training, scientists can be considered as having been socialized in a separate culture.[b] This separate culture takes a different approach to risk than the public does. Scientists, as a whole, have been shown to perceive less nuclear-related risk than the public;[43] for example, scientists believe that nuclear wastes are less risky than most lay persons believe they are.

In addition, subcultures within the scientific culture itself hold different views of risk. Barke and Jenkins-Smith[43] have found that scientists' views of nuclear risk correlate to their field (e.g., physics, biology, and engineering) and to their type of employer (e.g., Federal Government, local government, and academia). For instance, scientists working for the Federal Government judge the risks posed by nuclear waste to be less severe than do scientists in local governments and academia, and physical scientists perceive nuclear risks to be lower than do life scientists. In addition, scientists working for the Federal Government consider environmental restrictions to be a less valid means for dealing with nuclear risks than do those employed by universities or local government. In sum, scientists who work for local governments and academia have views of risk closest to those of the general public; those working for the Federal Government hold the views of risk furthest from those of the public. Thus NRC scientists, with their physical science background and federal employment, are likely to view risk very differently than the public.

The work that scientists perform can further condition their views of risk; for example, work that involves modeling, such as of reactor accidents, is likely to make its practitioners prone to a particular cognitive bias—*illusion of control.* Illusion of control occurs

[b]Vocational selection may also be a factor in explaining why scientists differ from other groups. Research on vocational selection indicates that people are drawn to fields and jobs that match their interests and preferences; for example, according to a well-respected personality diagnostic (Myer-Briggs), the majority of people in the United States are extroverts, whereas the majority of scientists are introverts. This is an important difference because introverts tend to focus on the inner world of ideas, and extroverts, on the outer world of people. Thus scientists may be predisposed by their very personalities to approach risk differently—more conceptually and less personally—than the public.

when people acquire the impression of having more control over outcomes than is justified. Illusion of control has been shown to occur in individuals when they have spent time analyzing a situation or observing a sequence of successful outcomes.[33,34] Thus those who go through the thought processes intrinsic to modeling are particularly prone to this cognitive bias. This bias could cause them to unconsciously underestimate the magnitude of uncertainty present in the model.[44] As a result, they could tend to give more credence to the model's predictions than is warranted.

SUMMARY

This work was initiated to explore some questions about how people think about risk. In this section, the findings will be summarized by questions.

• **Why do technical experts and regulators view risk so differently than the public?** Cultural conditioning is largely responsible for the different approaches to risk. Technical experts and regulators are mostly scientists and as such have been socialized by their educations, work, peers, and organizations to view risk differently than the public.

• **Why has informing the public of risk findings—the approach used throughout the government—had so little effect? How do feelings enter into thinking about risk? In particular, why are the public's feelings about nuclear risk so resistant to change or scientific counterargument?** Informing the public about the results of science-based risk analyses and assessments does not change their thinking for several reasons. First, for people to accept the scientific views of risk, they must view "science," or at least rationality, as a higher authority. They would be more likely to do so if they had received the same cultural conditioning as scientists. Because they have not, the public is likely to have their own ideas of higher authority and question the pronouncements of science in their personal lives.[6,45] Then, too, the public's views of risk are affected, usually negatively, by their confidence in those managing the technology.[11,12] Second, much of the public's thinking about nuclear risk involves averse feelings, and these feelings have been identified as resistant to change. Averse feelings may be long lasting because of the way in which emotions are learned or because of their link to a survival mechanism—the fear response.

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