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Advancing Understanding of Knowledge's Role in Lay Risk Perception

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Introduction

In the last two decades, scholars, agencies and firms have become increasingly interested in why laypeople see something as a threat. Curiosity, worry over scientific illiteracy, and social conflicts over potential threats foster the field of risk perception, a misleading but standard term. Many hope research on lay perception will help resolve conflicts, a hope that colors the focus and findings of many studies.

Knowledge about hazards plays a central but curious role in risk perception research. Knowledge *is* and *should be* important in risk perception; if not, humans would have died out long ago. Most people doing or funding this research know more about specific hazards than the average citizen. Yet their expertise blinds them to the complexity of hazard knowledge, and they take the importance of their own knowledge for granted. For example, most studies have probed only how knowledge affects lay risk perceptions, ignoring similar questions about experts and often dismissing lay concerns. Such pride and oversimplification have meant missing important aspects of hazard knowledge.

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This paper emphasizes how knowledge affects lay risk perception, citing the role of experts' knowledge in *their* risk perceptions only when needed to point up the narrowness of some current views on lay knowledge. The paper summarizes studies of knowledge in lay risk perception that have used three different foci (facts, cognitive heuristics or rules of thumb, and mental models). It then outlines some challenges of defining knowledge, beginning with the current treatment of knowledge and ignorance as endpoints on a single dimension, ignoring multiple dimensions of both. The utility of focusing on facts rather than conceptual structures is doubtful, and the usual distinction between direct (experience) and indirect knowledge is inadequate. The last definitional problem discussed is the way in which the term risk "perception" confuses quite different aspects of response to hazards.

The next section reviews how further research on three aspects of knowledge use can advance understanding of its role in lay risk perception. The first aspect discussed is knowledge production, with assessments of the effect of differing producers and aims, and alleged differences between the discovery and justification of knowledge. The second aspect discussed is knowledge dissemination, with a comparison of the huge (but often misleading) literature on the effects of mass media to the relative neglect of the role of social networks. The last aspect of knowledge use reviewed is that of information processing, concerning heuristics, risk aversion, after-the-fact justifying of behavior, and the serious efforts many laypeople make to understand science for their own ends. The paper ends by suggesting that improvements in studying lay knowledge can illuminate experts' hazard knowledge as well.

Studies of Knowledge in Risk Perception

Research on knowledge and lay risk perception falls into two major categories and a third, smaller class: (1) evaluating public grasp of facts about nature and technology for their effect on attitudes toward hazard; (2) identifying heuristics with which people process information on hazards; and (3) describing laypeople's conceptual frameworks for hazards.

The factual approach has been most common, although the heuristics results are better known. Most factual studies focused on radiation, trying to relate knowledge to public support or opposition to facilities (nuclear power, nuclear waste) or to individual behavior (radon testing and mitigation). These studies defined knowledge as "correct" answers to factual questions, such as "What is the name of the process that generates energy in nuclear power plants?" and "What is the fuel used in nuclear fission plants?" About half of these studies found that people who know more such facts support nuclear power; the other studies found no difference in knowledge among pro- and anti-nuclear laypeople, or that anti-nuclear people know more.[1] A few other studies, using similar factual measures, concerned irradiated food,[2] groundwater pollution,[3] hazardous waste cleanup,[4] air pollution,[5] hazardous waste, surface water pollution, automobile collisions,[6] natural radon,[7] and earthquakes.[8] Some found more knowledge linked to lower concern

1 *See, e.g.*, BARBARA D. MELBER ET AL., NUCLEAR POWER AND THE PUBLIC: ANALYSIS OF COLLECTED SURVEY RESEARCH (Battelle Human Affairs Research Center, 1977); James H. Kuklinski, Daniel S. Metlay & W.D. Kay, *Citizen Knowledge and Choices on the Complex Issue of Nuclear Energy*, 26 AM. J. POL. SCI. 615 (1982); Jennifer Brown, Terence Lee & Joyce Henderson, *Public Perception of Nuclear Power* (British Psychological Society, London, Dec. 1983); STANLEY M. NEALEY, BARBARA D. MELBER & WILLIAM L. RANKIN, PUBLIC OPINION AND NUCLEAR ENERGY (1983); and JOHN M. WILKES & JOHN H. REED, PUBLIC KNOWLEDGE AND INTERPRETATION OF NUCLEAR POWER BEFORE AND AFTER TMI (unpublished, Worcester Polytechnic Institute 1985).

2 Richard J. Bord & Robert E. O'Connor, *Risk Communication, Knowledge, and Attitudes: Explaining Reactions to a Technology Perceived as Risky*, 10 RISK ANAL. 499 (1990).

3 BONNEY F. HUGHES, KNOWLEDGE, BELIEFS AND ACTIONS OF ELMIRA WATER CUSTOMERS RELATED TO GROUNDWATER, CONTAMINATION OF GROUNDWATER, AND TOXICOLOGY (M.S. thesis, Cornell University 1986).

4 Richard J. Bord & Robert E. O'Connor, *Determinants of Risk Perceptions of a Hazardous Waste Site*, 12 RISK ANAL. 411 (1992).

5 Brian R.N. Baird, *Tolerance for Environmental Health Risks: The Influence of Knowledge, Benefits, Voluntariness, and Environmental Attitudes*, 6 RISK ANAL. 425 (1986).

6 Branden B. Johnson & Bradley Baltensperger, *Community Risk Perception: A Pilot Study*, in RISK ASSESSMENT AND MANAGEMENT 337 (Lester Lave ed. 1987).

7 Dominic Golding, Sheldon Krimsky & Alonzo Plough, *Evaluating Risk Communication: Narrative vs. Technical Presentations of Information About Radon*, 12 RISK ANAL. 27 (1992).

8 ALAN J. WYNER & DEAN E. MANN, SEISMIC SAFETY POLICY IN CALIFORNIA:

about risks (e.g., from hazardous waste cleanup) and more support for a technology's use (e.g., opposing a ban on irradiated food). Others found such relationships weak (e.g., irradiated food, air pollution) or negative (e.g., automobile collisions, earthquakes, natural radon). For example, those with more facts were more likely to demand protection against polluted groundwater. In short, the link between factual technical knowledge and perceived risk is at best variable.

A second research emphasis has been heuristics that people use to process information. One heuristic is availability, judging an event as more likely if it is easier to recall or imagine. For example, laypeople inexperienced with probabilities seem to overestimate the frequency of low-probability but dramatic hazards (e.g., nuclear power plant accidents), as compared to expert risk estimates. They also underestimate high-probability hazards that are less memorable, like some diseases.[9] People's risk perceptions also seem strongly affected by how a problem is framed or presented. For example, their estimates of death rates varied by whether they were asked for deaths or survivals, rates or frequencies.[10] These findings have been widely taken to mean that lay heuristics and statistical illiteracy bias lay risk estimates, and thus evaluations of danger, away from those of experts. Such views ignore warnings by heuristics researchers and others that these problems also affect hazard experts, making comparisons of "accurate" expert and "distorted" lay views misleading.[11]

LOCAL GOVERNMENTS AND EARTHQUAKES (Report to the National Science Foundation) (1983).

9 Sarah Lichtenstein et al., *Judged Frequency of Lethal Events,* 4 J. EXP. PSYCH.: HUM. LEARNING & MEMORY 551 (1978). These results were replicated by Engineering and Public Policy, Carnegie Mellon University Graduate Research Methods Class, *On Judging the Frequency of Lethal Events: A Replication,* 3 RISK ANAL. 11 (1983).

10 BARUCH FISCHHOFF & DONALD MACGREGOR, JUDGED LETHALITY (Decision Research, Inc. 1980).

11 M. HYNES & ERIC VANMARCKE, RELIABILITY OF EMBANKMENT PERFORMANCE PREDICTION (Proceedings of the ASCE Engineering Mechanics Division Specialty Conference) (1976); Jonathan Borak & Suzanne Veilleux, *Errors of Intuitive Logic Among Physicians*, 16 SOC. SCI. & MED. 1939 (1982); William R. Freudenburg, *Perceived Risk, Real Risk: Social Science and the Art of Probabilistic Risk Assessment*, 242 SCIENCE 42 (1988); Brian Wynne, *Sheepfarming After Chernobyl: A Case Study in Communicating Scientific Information,* 31 ENV. 10-15, 33-40 (1989); Kristin S. Shrader-Frechette, *Scientific Method, Anti-Foundationalism and*

The latest category of knowledge studies tries to describe the conceptual structure of lay hazards knowledge. One study revealed this structure implicitly through surveys revealing that laypeople and experts disagree strongly on many points of toxicology. For example, many laypeople do not conceive of exposure as mediating between chemical releases and health effects. Yet, both experts and laypeople disagreed among themselves about how animal tests apply to humans.[12] A more explicit approach to conceptual structure comes under the rubric of "mental models." A group of U.S. researchers began by assessing experts' conceptual structure for the events leading to a given hazardous outcome (e.g., cancer from natural radon, deaths due to nuclear energy sources in space, damage from floods).[13] They then identified concepts members of the public hold on the topic, through open-ended interviews and surveys, and compared them with the experts' conceptual structure. German researchers have used a somewhat different approach to study mental models of pharmaceutical drugs.[14] No one has yet explicitly tested how mental models might affect perceived risk.

Use of expert knowledge as the baseline has yielded ambiguous results on knowledge's effect on lay risk perception. To assess the importance of knowledge in citizens' views of hazard given contradictory evidence, we must examine the flaws of past studies, rather than simply continue to replicate them.

Public Decisionmaking, 1 RISK 23 (1990).

12 Nancy Kraus, Torbjorn Malmfors & Paul Slovic, *Intuitive Toxicology: Expert and Lay Judgments of Chemical Risks,* 12 RISK ANAL. 215 (1992).

13 Tamara R. Lave & Lester B. Lave, *Public Perception of the Risks of Floods: Implications for Communication,* 11 RISK ANAL. 255 (1991); Michael Maharik & Baruch Fischhoff, *The Risks of Using Nuclear Energy Sources in Space: Some Lay Activists' Perceptions,* 12 RISK ANAL. 383 (1992); Ann Bostrom, Baruch Fischhoff & M. Granger Morgan, *Characterizing Mental Models of Hazardous Processes: A Methodology and an Application to Radon,* J. SOC. ISSUES, *in press.*

14 Helmut Jungermann, Holger Schutz & Manfred Thuring, *Mental Models in Risk Assessment: Informing People about Drugs,* 8 RISK ANAL. 147 (1988). For a methodological discussion, *see* William B. Rouse & Nancy M. Morris, *On Looking into the Black Box: Prospects and Limits in the Search for Mental Models,* 100 PSYCH. BULL. 349 (1986).

Defining Knowledge

Scientific advances depend upon properly defining the issue of study; scholars can dispute whether given definitions support or stifle progress, but limits must be set. Unfortunately, research on knowledge and risk perception has used poor taxonomies and definitions that wrongly seem self-evident. These concern the relations of knowledge and ignorance, facts and conceptual structures, direct and indirect knowledge, and distinct aspects of what is known as "risk perception."

Knowledge versus Ignorance

Almost all of this research assumes that knowledge has one dimension, with people having more or less of it. This view depends upon critical assumptions, i.e. that experts know all that is important about hazards, and social conflict stems solely or primarily from lay ignorance. In this view one can ignore citizens' views on policy: Either they do not know whereof they speak or they will simply agree with experts' prior conclusions. Advocates of this view infer two answers to conflict. For hazards outside lay individuals' control, the preferred method is put trust in, and delegation of hazard management to, experts. A second method is to educate citizens, assuming this would shift public attitudes toward those of experts. William Ruckelshaus, former Environmental Protection Agency (EPA) Administrator, supported this approach, if uneasily:[15]

> In confused situations one must try to be guided by basic principles. One of my basic principles is reflected in a quotation from Thomas Jefferson: "If we think [the people] not enlightened enough to exercise their control with a wholesome discretion, the remedy is not to take it from them, but to inform their discretion." Easy for *him* to say.

Taking knowledge and ignorance as ends of a continuum is, however, a caricature even of specific scientific fields. There are many types of ignorance, and therefore of knowledge. The taxonomy in Figure 1 points out that probability — the focus of both quantitative risk assessment and much concern about lay technical illiteracy — is only one branch of ignorance.[16]

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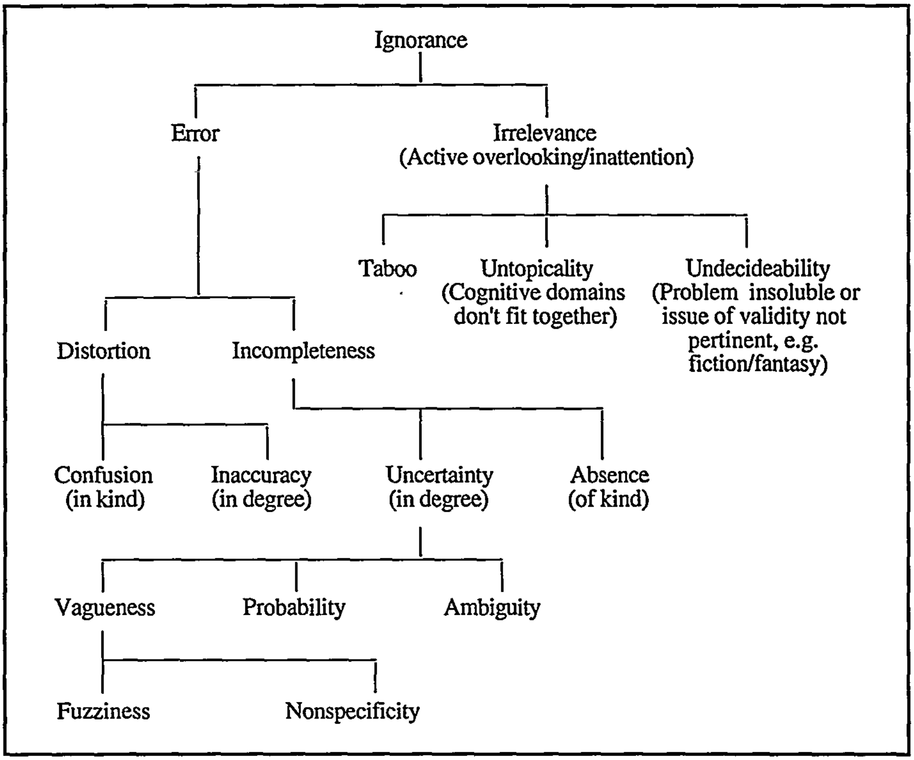
15 William D. Ruckelshaus, *Risk in a Free Society,* 4 RISK ANAL. 157, 160 (1984).

16 MICHAEL SMITHSON, IGNORANCE AND UNCERTAINTY: EMERGING PARADIGMS

Figure 1
Taxonomy of Ignorance



The hazards field's unduly narrow emphasis on probability may explain why researchers have scorned the idea that cultural taboos shape risk perception at least as much as uncertainty. What one should not think about may be more vital than how well one knows what one does think about.[17] One cannot assume that effective hazard response depends only upon knowing probabilities, nor that other kinds of knowledge offset a deficit in statistical skills. Yet, the one-dimensional view ignores the likelihood of multiple knowledges and ignorances.

An odd result of this blindness is that much risk perception research, particularly the "factual" variety, seems to banish even uncertainty.

(1989). [Figure 1 is adapted from Smithson, at 9.] *See also* SILVIO O. FUNTOWICZ & JEROME R. RAVETZ, UNCERTAINTY AND QUALITY IN SCIENCE FOR POLICY (1990).

17 MARY DOUGLAS & AARON WILDAVSKY, RISK AND CULTURE: AN ESSAY ON THE SELECTION OF TECHNOLOGICAL AND ENVIRONMENTAL DANGERS (1982).

Scholars tend to assume no variations in the data available to citizens, the character of inferences one can reasonably draw from the data, or the confidence one has in those inferences. The rich, subtle world of the practicing scientist or engineer becomes black-and-white when they review the alleged ignorance of lay risk perception. Ironically, hazards for which lay ignorance seems to upset experts most (e.g., nuclear power, chemical wastes, recombinant DNA) are often those for which expert knowledge is most uncertain.[18] In some cases experts may know little more than laypeople for the foreseeable future (e.g., in epidemiological studies of cancer clusters).[19]

Knowledge and ignorance exist for both laypeople and experts. Researchers' failure to consider multiple dimensions of knowledge and ignorance undermines one's confidence in the validity of their findings on lay knowledge and risk perception.

Facts versus Conceptual Structure

The factual studies cited earlier correlated correct answers to positive attitudes toward a technology, e.g., implying that facts learned change attitudes.[20] Researchers did not justify this approach, apparently taking it as obvious. Are isolated "facts" necessary, much less sufficient, for thought or discourse on a subject? Creationist arguments stem partly from assuming that the theory of evolution is merely a pile of facts. If one such fact is false, they believe the theory must collapse, a view at odds with scientific practice.[21] Fact-focused research on knowledge and hazards unwittingly bolsters the creationist argument.

Facts are also less definitive than often assumed. People who jointly see something should never be wholly confident that the group observed

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18 Freudenburg, *supra* note 11.

19 *Contrast* Raymond Neutra, Shanna Swan & Thomas Mack, *Clusters Galore: Insights About Environmental Clusters from Probability Theory,* 127 SCI. OF THE TOTAL ENV. 187 (1992); and Daniel Wartenberg & Michael Greenberg, *Methodological Problems in Investigating Disease Clusters,* 127 SCI. OF THE TOTAL ENV. 173 (1992).

20 Another hypothesis is that education expands cognitive capacity, allowing one to draw new conclusions from the same data and change one's attitude. However, this hypothesis cannot be tested with these studies' designs.

21 James B. Miller & Dean R. Fowler, *What's Wrong with the Creation/Evolution Controversy?* AAAS, May 1984.

reality. Simultaneous delusion, implicit or explicit social pressure to conform, and cognitive biases that are general (heuristic) or situational (e.g., how good is the evidence that this person died in an automobile collision?) may affect the observation. The problem is even more acute when hazards stem from events so rare or hypothetical that experts must create facts from their judgments to have any evidence. Facts become "strongly held beliefs shared by expert groups."[22] If strongly held risk beliefs that experts label as facts become bound to other expert beliefs about the benefit of a hazardous technology, for example, why should these expert beliefs become facts required for lay support for the same technology? Laypeople's experience can also make them skeptical of expert facts, as with farmers' experience of varied microenvironments and patients' experience of variability in their own or others' metabolisms.[23] Treating these reactions as wrong misconstrues the contingent place of facts in knowledge.

A rebuttal to this argument for contingent facts is that social context affects knowledge only during its discovery, as Newton's mysticism affected his choice of topics and methods. In contrast, getting others to validate one's discovery forces the use of objective evidence that will appeal to experts with other views.[24] However, this rebuttal is only partly true, assuming as it does that the only producers of hazard knowledge are scientists who wish to justify their data and interpretations to colleagues. But producers are not always scientists; they may not produce easily verifiable information; and their audiences (e.g., potential funders of scientific research) may not understand or find salient scientific defenses of data.

Also, the history and sociology of science (and, to a lesser degree, of technology) show social context also shapes justification, and thus

[22] Harry J. Otway & Detlof von Winterfeldt, *Beyond Acceptable Risk: On the Social Acceptability of Technologies,* 14 POL'Y SCI. 247 (1982); Freudenburg, *supra* note 11.

[23] Brian Wynne, *Knowledges in Context,* 16 SCI., TECH. & HUM. VALUES 111, 115 (1991).

[24] Joseph Ben-David, *Academic Market, Ideology, and the Growth of Scientific Knowledge: Physiology in Mid-Nineteenth Century Germany,* in SIEGWART LINDENBERG, JAMES S. COLEMAN & STEFAN NOWAK, APPROACHES TO SOCIAL THEORY 63 (1986).

knowledge.[25] Only the degree of social construction of the contexts of discovery and justification is in dispute. Scholars agree that scientific discourse and practice validate facts more than by simply displaying them to a jury of the discoverer's peers. Kuhn's idea of scientific paradigms,[26] although limited, ended the scholarly assumption that "the facts" decide scientific conflicts. Attempts to classify fields by the "hardness" of their knowledge — the chance that a hypothesis or theory will endure — are dubious. One must "ask *for whom*, in *what circumstances*, on *what occasions*, *how*, and *why* does this [field] appear hard...."[27] Similarly, scholars increasingly see a technology's attributes as a temporary, shifting outcome of complex social negotiation over what the technology is.[28] Unfortunately, even most scholars who view technology as a social construct apply this perspective only to items that evoke political conflict.[29] For both science and technology, at best consensus implies that the group is closer to reality than if its members did not agree, and such factors as social pressure for conformity could put them farther from reality.

The recent focus on conceptual structures may not remove the problems of factual studies, because the mental models approach implicitly treats technical facts and concepts as all that are important in hazard knowledge.[30] The method's value also depends upon the accuracy and completeness of the expert conceptual structure ("influence

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25 Steve Woolgar, *Interests and Explanation in the Social Study of Science*, 11 SOC. STUDIES OF SCI. 365 (1981); Michael Mulkay, *Looking Backward*, 14 SCI., TECH. & HUM. VALUES 441 (1989).

26 THOMAS S. KUHN, THE STRUCTURE OF SCIENTIFIC REVOLUTIONS (1962).

27 Steve Woolgar, *The Turn to Technology in Social Studies of Science*, 16 SCI., TECH. & HUM. VALUES 20 (1991).

28 Harry J. Otway & Kerry Thomas, *Reflections on Risk Perception and Policy*, 2 RISK ANAL. 69 (1982).

29 *See, e.g.*, Silvio O. Funtowicz & Jerome R. Ravetz, *Three Types of Risk Assessment: A Methodological Analysis*, in CHRIS WHIPPLE & VINCENT T. COVELLO, RISK ANALYSIS IN THE PRIVATE SECTOR 217 (1985); and Steve Rayner, *Risk and Relativism in Science for Policy*, in BRANDEN B. JOHNSON & VINCENT T. COVELLO, THE SOCIAL AND CULTURAL CONSTRUCTION OF RISK: ESSAYS IN THE SELECTION AND PERCEPTION OF RISK 5 (1987).

30 Branden B. Johnson, *The "Mental Model" Meets the "Planning Process": Wrestling with Risk Communication Research and Practice*, 13 RISK ANAL. 5 (1993).

diagram"). An influence diagram on floods omitted the critical effect of urbanization on runoff volume, a concept whose presence in urban residents' mental models of flood this study thus could not test.[31] More work must be done to define which concepts, expert or not, embody knowledge before a conceptual approach resolves the problems posed by fact-centered research methods.

Indirect Knowledge versus Experience

The literature distinguishes poorly between knowledge gained from personal experience and that from others' experience (e.g., through social networks, mass media or books). Experts and laypeople alike draw on both sources to make decisions; yet almost no hazards researchers have studied their effects on the same issue. Technological hazards researchers emphasize indirect knowledge, such as whether people know what fuel is used by most nuclear fission power plants. Natural hazards researchers emphasize experience; they attend to indirect knowledge primarily in terms of the impact of deliberate media campaigns to educate people about natural hazards. The fact that they find trivial impacts,[32] while mass media research on technological hazards (see "Dissemination" discussion below) often finds large media effects on public risk agendas, suggests the potential value of more inclusive research.

This division of labor is not entirely unjustified. Most people do not experience nuclear accidents, even those living next to a nuclear power plant. It is not even certain that people near Three Mile Island in 1979 experienced an accident, rather than a muddled evacuation and media coverage. It was labeled an accident (sometimes an inevitable one) by many people, both local residents and experts. Yet, varied responses to seemingly alike hazard events[33] and the idea that such responses can amplify or reduce both actual and perceived risk[34] suggest area residents

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31 Lave & Lave, *supra* note 13.

32 Thomas F. Saarinen, *The Relation of Hazard Awareness to Adoption of Mitigation Measures,* in PERSPECTIVES ON INCREASING HAZARD AWARENESS 1 (Saarinen ed. 1982).

33 EDWARD W. LAWLESS, TECHNOLOGY AND SOCIAL SHOCK (1977).

34 Roger E. Kasperson et al., *The Social Amplification of Risk: A Conceptual Framework,* 8 RISK ANAL. 177 (1988).

did not experience a simple accident. Natural hazards researchers have tended to focus on actual harms suffered, as opposed to the possible harms often the focus of technological hazards research. For such harms direct experience of flood surge or earthquake tremors seems more salient to researchers than prior messages from indirect sources about these dangers.

Ultimately, however, this division of focus between natural and technological hazards research is inadequate. It leaves out technological hazards with which people have much experience, such as automobiles, and how some people use indirect knowledge of natural hazards to avoid or prepare for tsunamis, floods, and the like. Academic contrasts between natural and technological hazards are premature.[35] To fully understand how people deal with hazards in the light of their knowledge, one must look at the role of both indirect and personal experience. For example, British sheepfarmers' grasp of the uncertainty inherent in their work, and doubt about previous official statements on radiation from a local reprocessing plant, led them to reject official overconfidence about the local effects of Chernobyl. Scientific data later supported the farmers' caution.[36] The interplay of indirect and direct knowledge becomes even more vital as research goes beyond experience with risky consequences (e.g., "I've been in a terrible automobile accident.") to experience with risk managers (e.g., "Has this agency credibly managed past problems that affected me or might have?").[37] Scholars have just begun to study what lay experiences (if any) with hazard managers affect perceived risk and trust in managers, much less use these experiences as measures of knowledge.[38]

Indirect knowledge and experience also differ in emotional power. Experience gives immediate sensory feedback, as in snowfall or the odors that often led New Jersey citizens to seek data on chemical

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35 George Cvetkovich & Timothy C. Earle, *Classifying Hazardous Events,* 5 J. ENV. PSYCH. 5 (1985).

36 Wynne, *supra* note 11.

37 Roger E. Kasperson, *Six Propositions on Public Participation and Their Relevance for Risk Communication,* 6 RISK ANAL. 275 (1986).

38 Branden B. Johnson, *Trust in Theory: Many Questions, Few Answers* (Soc'y Risk Anal. 1992).

emissions.[39] This contrast between knowledge and experience may imply different kinds of information processing, depending on its source or modality. As with the taste of a madeleine for Proust's narrator, the presence or absence of odor and other sensory signals may alter available memories, salient criteria, and apparent danger. Yet, the role of experience seems to vary widely. Sometimes visible signs provoke fear, as when people see factory steam as dangerous pollution or a tornado on the horizon as a sign of imminent danger. Sometimes they reassure, as when factory smoke symbolizes jobs.[40] The invisibility of radiation's link to cancer allegedly drives concern,[41] yet inability to see or taste toxic chemicals in drinking water seems sometimes to offer comfort.[42] Some scholars even argue that no alleged attribute of a hazard cause — whether an actual flood or the "dread" of nuclear power — can dependably determine hazard views.[43] Even if this minority belief goes too far, it show the fallacy in taking experience, or any other aspect of knowledge, as obvious or unambiguous.

Experience may fortify cognitive biases, such as overconfidence in one's risk estimates.[44] Survivors of natural disasters often downplay future risks: their survival confirms they can handle anything, while their non-probabilistic view of the world means "lightning never strikes

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39 BRANDEN B. JOHNSON, AN UNDERUSED RESOURCE: USERS' EXPERIENCES WITH AND EXPECTATIONS OF NEW JERSEY COMMUNITY RIGHT-TO-KNOW DATA (NJ DEPE–DSR 1991).

40 CHARLES O. JONES, CLEAN AIR (1975).

41 P.D. PAHNER, A PSYCHOLOGICAL PERSPECTIVE OF THE NUCLEAR ENERGY CONTROVERSY (RM-76-67, Int'l Instit. Applied Systems Analysis, 1976); R.L. DuPont, *Nuclear Phobia: Phobic Thinking About Nuclear Power,* in EDISON ELECTRIC INSTITUTE, NUCLEAR POWER IN AMERICAN THOUGHT, 23 (1980).

42 Janet M. Fitchen, Jenifer S. Heath & June Fessenden-Raden, *Risk Perception in Community Context,* in THE SOCIAL AND CULTURAL CONSTRUCTION OF RISK: ESSAYS ON RISK SELECTION AND PERCEPTION 31 (Branden B. Johnson & Vincent T. Covello eds. 1987).

43 Otway & Thomas, *supra* note 28; Steve Rayner, *Muddling Through Metaphors to Maturity: A Commentary on Kasperson et al., The Social Amplification of Risk*, 8 RISK ANAL. 201 (1988); MICHIEL SCHWARZ & MICHAEL THOMPSON, DIVIDED WE STAND: REDEFINING POLITICS, TECHNOLOGY AND SOCIAL CHOICE (1990). *See also,* Woolgar, *supra* note 27.

44 Neil D. Weinstein, *Unrealistic Optimism About Susceptibility to Health Problems,* 5 J. BEHAV. MED. 441 (1982).

twice in the same spot." Together these beliefs can lessen risk prevention and reduction, as laypeople and some scholars ignore the problem of how to measure exposure to a hazard event consistently. The latter sometimes use sampling techniques that confuse people who suffered hurricane-strength winds with those exposed to strong but weaker winds further from a storm's center. This sampling error results in failure to know whether people who "survived Hurricane Andrew" indeed had identical experiences. Whether indirect knowledge has identical effects on cognitive biases will remain unknown until researchers compare these two kinds of knowledge.

"Risk Perception"

Use of the term "risk perception" hampers progress. First, the term implies that lay views differ from what experts believe (and thus the way things really are). Second, it does not specify the changes in values, beliefs, attitudes or behavior that might result from a fact's presence or absence, or proper or improper use of a concept. For example, in one city experts and residents worried about possible health effects of pervasive chromate (hexavalent chromium) waste. Some experts fretted over a rumor that there were residents who believed chromium to be the name of a disease. Yet, such a misunderstanding is insignificant unless it prevents citizens from taking truly protective action, or from fully weighing their personal risk. Without clearly specifying what scholars and others mean by risk perception, however, one cannot properly evaluate such hypotheses about factual significance.

It would be better to distinguish among several different dependent variables that one might consider when referring to risk "perception."[45] First, there is issue attention: What makes a topic worthy of further study and, perhaps, concern? Knowledge is a common implicit answer. Yet, having one's house flooded every spring for ten years is but one knowledge underlying issue attention. Quite different knowledges create social or religious norms to trust or beware certain issues, institutions or behavior, and thus to pay special attention to potential sources of threat or benefit.[46]

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45 Branden B. Johnson, *Risk and Culture Research: Some Cautions,* 22 J. CROSS-CULTURAL PSYCH 141 (1991).

Many risk analysts presume that estimates of risk probabilities (i.e., knowledge) drive evaluation of a hazard's seriousness or worthiness of further action. Yet, lay risk estimates include not only a hazard event's likelihood or even its outcome, but other items less often seen as knowledge (e.g., dread, familiarity).[47] In addition, hazard evaluation stems only partly from valid risk estimates or the uncertainties in risk assessment.[48] Thus Norwegian students saw "unknown" hazards as insignificant, while Americans took the opposite view.[49]

Ideologies, the opinions of people within job or neighborhood networks, and other factors also affect a hazard's salience. For example, in a California referendum on nuclear power, those informed about nuclear power voted on the basis of ideology. The less knowledgeable voted for the position held by their most important reference group.[50] Knowledge as usually defined in hazards research may even be trivial in evaluation. The chance to be "for" one's country or "good science," or "against" drugs, abortion or government interference with private property may carry more weight than do risk estimates.

Attribution of cause and responsibility (e.g., praise or blame) for hazard entails other knowledges. Pertinent "facts" might include the identities of potentially responsible parties, those most likely to be responsible given the available facts, and those who should have known and prevented the threat but refused to do so despite clear obligations to act. Yet, knowledge may not be the strongest factor in attribution. For example, ideology can help one allocate responsibility whether one has, or even seeks, information about who can choose to prevent or advance a given outcome.[51] Even when knowledge has an effect, it may not be

46 Rayner, *supra* note 43.

47 Paul Slovic, Baruch Fischhoff & Sarah Lichtenstein, *Facts and Fears: Understanding Perceived Risk,* in SOCIETAL RISK ASSESSMENT: HOW SAFE IS SAFE ENOUGH? 181 (Richard C. Schwing & W.A. Albers, Jr. eds. 1980).

48 Freudenburg, *supra* note 11.

49 Karl H. Teigen, Wibecke Brun & Paul Slovic, *Societal Risks as Seen by a Norwegian Public,* 1 J. BEHAV. DEC. MAKING 111 (1988).

50 Kuklinski et al., *supra* note 1.

51 Steve Rayner & Robin Cantor, *How Fair Is Safe Enough?* 7 RISK ANAL. 3 (1987).

the one expected by experts. Poor and working-class citizens who gained knowledge as they became environmental activists also gained fear and anger at government betrayal.[52]

Knowledge of feasible actions partly affects the strategy one uses to get hazard controls enacted (e.g., vote, lobby government, violence). But feasibility depends upon more than knowledge of costs, benefits, and available resources. One also takes into account capacity to affect others' behavior, ability to justify the strategy as proper (e.g., moral), tradition, desire to avoid or foment conflict, compliance or resistance to orders, and seizure of unexpected openings. These knowledges do not fit easily into current approaches. One reason for that may be that much interest in knowledge's role in risk "perception" concerns action rather than thought. Many hazard managers, for example, want people to stop becoming activists and being rude at public meetings. To a great extent, their public relations pain comes from ignoring the frequent influence of non-knowledge factors in strategic behavior, including their own.

The same applies to preferences for certain hazard controls over others. Knowledge about technical suitability is important, but political, cultural, and moral issues are critical as well (e.g., many environmentalists resist use of nuclear power to avoid global warming, or auctions to reduce air pollution). Economic resources also limit people's ability to act upon credible advice; institutions that justify limited environmental sampling or chemical tests by lack of money[53] often fail to recognize this constraint on others. Radon remediation may be (or seem) too costly, for example, or people interested in an informational briefing may not attend for lack of child care. Apathy or uncritical trust are reasonable for people who lack resources or a sense of control. Residents of a wealthy town, by contrast, may prefer more costly hazard controls than those advised by experts (e.g., to lower radiation in ground water)[54] if they apparently avoid more risk that way.

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52 HAL ARONSON, BECOMING AN ENVIRONMENTAL ACTIVIST: THE PROCESS OF TRANSFORMATION FROM EVERYDAY LIFE INTO MAKING HISTORY IN THE HAZARDOUS WASTE MOVEMENT (Am. Sociol. Assn., 1992).

53 David Ozonoff & Leslie I. Boden, *Truth and Consequences: Health Agency Responses to Environmental Health Problems,* 12 SCI., TECH. & HUMAN VALUES 70 (1987).

Thus, the ways that we create, discover and respond to hazards are far more varied than "risk perception" implies. Although scholars may retain that term, they must specify the attitudes and behavior they study if knowledge research results are to be comparable across studies.

Aspects of Hazard Knowledge Use

The research on hazard knowledge discussed earlier takes facts and concepts as things people either know or don't know, ignoring dynamic aspects of knowledge use. People produce and disseminate, as well as process, information; in all three cases knowledge's definition and interpretation can vary greatly, shifting its effects on hazard recognition.

Production

Knowledge acquires meaning only in specific social contexts. One important contextual attribute is the purpose for which one makes new knowledge. Is it to estimate the risk of a technology or natural event? select the best hazard control? decide which hazard to study, or whether to manage hazards rather than tackle another part of life? Each purpose alters the questions one asks and the answers one (sometimes) hopes for, and thus changes the likely answers. For example, knowledge made by and for professional hazard managers frames the facts differently than when they appear in the everyday world. In that world most people (including off-duty risk professionals) cope with possible hazards simply as aspects of life, rather than as "risks."[55] Purposes also vary across stages of knowledge development, thus changing cognitive and technical bases. For example, in the academic world alone casual queries, formal research applying established theory to a new area, and exploratory research aimed at theory development diverge on hoped-for answers, salient data, and necessary analytical techniques, among other attributes. These contrasts change the knowledge produced.

Knowledge also varies by its producer. Government, industry, environmentalists and professors have varied aims, e.g., risk estimates

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54 Frank Langfitt, *In One Township, Radium Issue Runs Deep,* Philadelphia Inquirer, July 30, 1989, at B1, B6.

55 Otway & Thomas, *supra* note 28; Harry Otway & Brian Wynne, *Risk Communication: Paradigm and Paradox,* 9 RISK ANAL. 141 (1989).

may be for internal use, or to publicly defend or oppose regulation. A near-bankrupt firm may estimate lower risks than does a corporation that can afford new regulations that might hurt its weaker competitors if it can get its estimates enacted in agency standards. With multiple producers comes potential conflict, further shaping knowledge. Taken-for-granted facts do not have the same epistemological or political status as challenged premises, even for their proponents.[56]

How laypeople produce knowledge is unknown, because scholars have assumed citizens' knowledge depends only on their receipt and understanding of expert knowledge. Yet, if experience is truly knowledge, laypeople produce hazard knowledge that is not simply a distortion of science. Anecdotal data also suggest that citizens use analogies to help decide whether and who to trust, or to make other hazard-related judgments, on issues such as radioactive waste.[57] It is unknown whether such lay-produced knowledge interferes with or complements understanding and acceptance of expert knowledge; such effects probably vary across topics and knowledge producers. Sheepfarmers' experiences led them to doubt (in retrospect, aptly) official statements on local effects of Chernobyl. At least once "mere" housewives identified local health effects of a chemical and got EPA agreement (after much resistance) to severely restrict use.[58] Citizens have often championed alternatives to manage local solid and hazardous waste problems. If the technical and economic wisdom of some of these is suspect, lay efforts to produce (or exploit) knowledge other than that of institutions is not. Such knowledge is not necessarily superior to that of experts, but its effects on hazard response and political debate cannot be ignored if understanding of hazards knowledge is to improve.

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56 LIORA SALTER, MANDATED SCIENCE: SCIENCE AND SCIENTISTS IN THE MAKING OF STANDARDS (Dordrecht, Holland: Kluwer, 1988); Paul Slovic, Nancy Kraus & Vincent T. Covello, *Comment: What* Should *We Know About Making Risk Comparisons?* 10 RISK ANAL. 389 (1990).

57 *See, e.g.*, MICHAEL E. KRAFT, BRUCE B. CLARY & JAMES SCHAEFER, POLITICS, PLANNING AND TECHNOLOGICAL RISKS: STATE AND CITIZEN PARTICIPATION IN NUCLEAR WASTE MANAGEMENT 3 (Am. Polit. Sci. Assn., 1987); RICHARD W. STOFFLE ET AL., SOCIAL ASSESSMENT OF SITING A LOW-LEVEL RADIOACTIVE WASTE STORAGE FACILITY IN MICHIGAN (1990).

58 Jeffrey Smith, *EPA Halts Most Use of Herbicide 2,4,5-T,* 203 SCIENCE 1090 (1979).

Dissemination

How people convey knowledge to others also shapes knowledge content. This is partly recognized by experts who blame the mass media for lay ignorance: if only reporters weren't so ignorant of science, quoted the right sources, and didn't sensationalize, the public would be much wiser about hazards. There is some truth to this assertion, yet it obscures as much as it reveals. The media do not cover types and attributes of hazards as many experts would, but the gap is smaller than assumed.[59] Media reports may overstate or misconstrue the basis of conflict over hazards, but rarely produce conflict.[60] Even with "balanced" coverage the very number of hazard stories might raise concerns, although the evidence for this hypothesis is mixed.[61] What sources say, correctly quoted, can affect perceived risk as much as who is quoted,[62] and agencies, firms, and others actively seek to get their messages out.[63] Thus sources help create media "distortions." Media select sources partly to display conflict, yet "extreme" sources (e.g., industry vs. environmentalists) are rare compared to government officials or even the "person in the street." Extreme views tend to be filtered out.[64] Coverage can affect both the public's and policy elites'

[59] Barbara Combs & Paul Slovic, *Newspaper Coverage of Causes of Death,* 56 JOURN. Q. 837 (1979); SCIENTISTS AND JOURNALISTS: REPORTING SCIENCE AS NEWS (Sharon M. Friedman, Sharon Dunwoody & Carol L. Rogers eds. 1986); PETER W. SANDMAN, DAVID B. SACHSMAN & MICHAEL R. GREENBERG, THE ENVIRONMENTAL NEWS SOURCE: INFORMING THE MEDIA DURING AN ENVIRONMENTAL CRISIS (1987); Allan Mazur, *Nuclear Power, Chemical Hazards, and the Quantity of Reporting,* 1990 MINERVA 294.

[60] Roger E. Kasperson et al., *Social Amplification of Risk: The Media and Public Response,* in WASTE MANAGEMENT '89: WASTE PROCESSING, TRANSPORTATION, STORAGE AND DISPOSAL, TECHNICAL PROGRAMS AND PUBLIC EDUCATION, 1 HIGH-LEVEL WASTE AND GENERAL INTEREST 131 (R.G. Post ed. 1989).

[61] Allan Mazur, *Media Coverage and Public Opinion on Scientific Controversies,* 31 J. COMMUN. 106 (1981); David L. Protess et al., *The Impact of Investigative Reporting on Public Opinion and Policymaking: Targeting Toxic Waste,* 51 PUB. OPINION Q. 166 (1987); Kasperson et al., *supra* note 60; Mazur, *supra* note 59.

[62] MEDIA INSTITUTE, CHEMICAL RISKS: FEARS, FACTS, AND THE MEDIA (1985); Friedman et al., *supra* note 59; Sandman et al., *supra* note 59.

[63] OSCAR H. GANDY, JR., BEYOND AGENDA SETTING: INFORMATION SUBSIDIES AND PUBLIC POLICY (1982).

[64] Media Institute, *supra* note 62; Sandman et al., *supra* note 59.

hazard views, so that media agendas do not affect merely (or even mostly) an allegedly vulnerable lay public. Media effects vary by whether one measures what people think of a hazard or what hazards they think about, identifies effects with a survey or experiment,[65] and controls for other knowledge or traits of media users, e.g., hazard experience.[66] No universally valid statement about media effects on public hazard agendas exists. What people seek from media — facts or amusement — and their frameworks, e.g., ideology, for media data also affect what they attend to, understand and accept.[67]

The focus on mass media ignores another, potentially potent distributor of hazard information: social networks. Those we talk to, and about what, have effects far beyond a simple delivery (or distortion, as in rumor) of data. Discussions with family, friends, neighbors and co-workers reinforce or offset mass media effects. Discussions help people decide what raw or pre-digested data mean,[68] although they may not foster more reflection than solitary analysis. Hazards and human responses also may create or destroy social networks, as at Love Canal,

65 PHILLIP J. TICHENOR, GEORGE A. DONOHUE & CLARICE N. OLIEN, COMMUNITY CONFLICT AND THE PRESS (1980); MICHAEL B. MACKUEN & STEVEN L. COOMBS, MORE THAN NEWS: MEDIA POWER IN PUBLIC AFFAIRS (1981); SHANTO IYENGAR & DONALD R. KINDER, NEWS THAT MATTERS: TELEVISION AND AMERICAN OPINION (1987); DAVID P. FAN, PREDICTIONS OF PUBLIC OPINION FROM THE MASS MEDIA: COMPUTER CONTENT ANALYSIS AND MATHEMATICAL MODELING (1988).

66 MEDIA POWER IN POLITICS (Doris A. Graber ed. 1984); Dorothy Nelkin (Background Paper), in TWENTIETH CENTURY FUND TASK FORCE ON THE COMMUNICATION OF SCIENTIFIC RISK, SCIENCE IN THE STREETS, 21 (1984); MICHAEL MACKUEN, ROBERT ERIKSON & JAMES A. STIMSON, ON THE IMPORTANCE OF ECONOMIC EXPERIENCE AND EXPECTATIONS FOR POLITICAL EVALUATIONS (Am. Polit. Sci. Assn., 1988).

67 THE USES OF MASS COMMUNICATION: CURRENT PERSPECTIVES ON GRATIFICATIONS RESEARCH (Jay G. Blumler & Elihu Katz eds. 1974); DENNIS HOWITT, MASS MEDIA AND SOCIAL PROBLEMS (1982); MEDIA GRATIFICATIONS RESEARCH: CURRENT PERSPECTIVES (Karl Erik Rosengren, Lawrence A. Wenner & Philip Palmgreen eds. 1985); Harold I. Sharlin, *Macro-Risks, Micro-Risks, and the Media: The EDB Case,* in THE SOCIAL AND CULTURAL CONSTRUCTION OF RISK: ESSAYS IN THE SELECTION AND PERCEPTION OF RISK, 183 (Branden B. Johnson & Vincent T. Covello eds. 1987).

68 Tom R. Tyler, *Assessing the Risk of Crime Victimization: The Interaction of Personal Victimization Experience and Socially Transmitted Information,* 40 J. SOC. ISSUES 27 (1984); Susan J. Smith, *News and the Dissemination of Fear,* in GEOGRAPHY, THE MEDIA, AND POPULAR CULTURE, 229 (Jacquelin Burgess & John R. Gold eds. 1986).

altering the information that members seek, receive and produce.[69] Social networks include people one wants to protect (e.g., children), affecting one's concerns, questions and reasons for seeking, understanding and accepting answers.[70] In short, dissemination channels do not simply convey information with varying precision and accuracy; whether mass media or personal, they actively affect what counts as knowledge for various audiences.

Information Processing

This aspect of hazard knowledge has received much attention through pioneering work on heuristics as discussed above. Yet, many scholars and practitioners mistake the implications of these results, beyond wrongly assuming experts' immunity to cognitive biases (see "Studies of Knowledge," above). Most data on heuristics come from experiments whose design may make heuristics misleading; heuristics may be more useful in the real world except for rare, perhaps not yet experienced, disasters.[71] Experiments also exclude factors that might offset or worsen distortion due to heuristics. These include being accountable to others for one's risk estimate,[72] social norms,[73] talk with others before estimating risks[74] and assumptions that problems are

69 Martha R. Fowlkes & Patricia Y. Miller, *Chemicals and Community at Love Canal*, in THE SOCIAL AND CULTURAL CONSTRUCTION OF RISK: ESSAYS IN THE SELECTION AND PERCEPTION OF RISK, 55 (Branden B. Johnson & Vincent T. Covello, eds. 1987).

70 Howitt, *supra* note 67; Lawrence C. Hamilton, *Concern About Toxic Wastes: Three Demographic Predictors*, 28 SOC. PERSP. 463 (1985).

71 Baruch Fischhoff & Ruth Beyth-Marom, *Hypothesis Evaluation From a Bayesian Perspective*, 90 PSYCH. REV. 239 (1983); Lola L. Lopes, *Some Thoughts on the Psychological Concept of Risk*, 9 J. EXP. PSYCH.: HUM. PERC. & PERF. 137 (1983); Lawrence D. Phillips, *A Theoretical Perspective on Heuristics and Biases in Probabilistic Thinking*, in ANALYSING AND AIDING DECISION PROCESSES, 525 (Patrick Humphreys, Ola Svenson & Anna Vari eds. 1983); ALVIN I. GOODMAN, EPISTEMOLOGY AND COGNITION (1986); CARL GUSTAF HOYOS, ATTITUDES TO AND ACCEPTANCE OF UNCERTAIN SITUATIONS: THE VIEWPOINT OF PSYCHOLOGY, SOCIETY AND UNCERTAINTY, 49 (1987); Freudenburg, *supra* note 11; Smithson, *supra* note 16.

72 Peter J.D. Carnevale, *Accountability of Group Representatives and Intergroup Relations*, in EDWARD J. LAWLER, ADVANCES IN GROUP PROCESSES, 227 (1985).

73 George Wright, *Organizational, Group, and Individual Decision Making in Cross-Cultural Perspective*, in WRIGHT, BEHAVIORAL DECISION MAKING, 149 (1985); S.H. IRVING & J.W. BERRY, HUMAN ABILITIES IN CULTURAL CONTEXT (1988).

serious only if regulated by government.[75]

Other influences on information processing have received far less attention than heuristics. For example, laypeople who are risk-averse[76] either distort or do not process information. Yet, experts' concern about risk aversion ignores variation across people, times and situations, and in its effects on use of knowledge. Thus, people unable to cope with a threat do not deny risk if they still hope to gain control; instead, they seek information relating to such control.[77] They may become "popular epidemiologists" to get data government does not (and perhaps cannot) provide, thus avoiding risk by seeking information.[78] Often researchers see only how risk aversion affects others' definitions and processing of knowledge, not how it affects their own work.

Sometimes information processing, as psychologists use the term, does not occur. Actions can happen without much thought, justified later (knowingly or otherwise) with reasons other than the real reasons. Hazards scholars err if they take these statements at face value. It is more prudent to treat them as verbal behaviors whose relation to remedial or other actions must be examined, not merely assumed.

Another slighted aspect of processing is people's focus on helpful information, an obvious focus often overlooked by alleged hazard educators. Officials offering whole-body radioactivity scans and refusing water analyses to British farmers after Chernobyl did not understand the farmers' anger. Yet, the latter felt they could do nothing with the first kind of information, while water supplies could be

74 MARY DOUGLAS, RISK ACCEPTABILITY ACCORDING TO THE SOCIAL SCIENCES (1985); John Ziman, *Public Understanding of Science,* 16 SCI., TECH. & HUM. VALUES 99 (1991).

75 DOMINIC GOLDING, SHELDON KRIMSKY & ALONZO PLOUGH, RADON RISK COMMUNICATION IN CONTEXT: AN EXPERIMENT IN MASSACHUSETTS (Report to EPA) (1990).

76 NEIL D. WEINSTEIN, ATTITUDES OF THE PUBLIC AND THE DEPARTMENT OF ENVIRONMENTAL PROTECTION TOWARD ENVIRONMENTAL HAZARDS (Final Report of Study 2 in Public Perceptions of Environmental Hazards, NJ DEP 1988); Kraus et al., *supra* note 12.

77 Pieter-Jan M. Stallen & Arend Tomas, *Public Concern About Industrial Hazards,* 8 RISK ANAL. 237 (1988).

78 Phil Brown, *Popular Epidemiology: Community Response to Toxic Waste-Induced Disease in Woburn, Massachusetts,* 12 SCI., TECH. & HUM. VALUES 78 (1987).

changed if there was a problem.[79]

Finally, researchers and hazard professionals who doubt laypeople's ability to process technical knowledge overlook:[80]

> ...the enormous amount of sheer *effort* needed for members of the public to monitor sources of scientific information, judge between them, keep up with shifting scientific understandings, distinguish consensus from isolated scientific opinion, and decide how expert knowledge needs qualifying for use in *their* particular situation. They must also judge what level of knowledge is *good enough* for them. This is not necessarily the same level as scientists have assumed; the threshold may be looser, or tighter.

However limited the understanding of life's dangers reached by this process, researchers too often fail to recognize the achievements of laypeople who take on this task.

Conclusions

Ultimately knowledge is meaningful information. Meaning is not inherent in information; it requires interpretation to turn mere data into something that can be analyzed and acted upon. Research on the role of hazard knowledge in thought and action has tended to abstract from the daily contexts in which knowledge becomes real for people, whether laypersons or experts. Such abstraction has undermined the confidence with which analysts can treat these findings. This paper has stressed factors that undercut the effects of knowledge on hazard responses, but one must treat even these hypotheses with caution given the poor definitions and taxonomies of hazard knowledge now available.

Some may take the case for both greater clarity and a broader definition of hazards knowledge, and criticism of factual and technical emphases, as advocating relativism. That is false, and failure to follow this agenda may actually foster relativism. Risk assessment and hazard management have flaws, even discounting some popular criticisms driven more by ideology than by logic. As such flaws become more obvious, society faces a potentially sterile choice. It either wholly rejects

79 Wynne, *supra* note 23 at 117.

80 *Id., original emphasis.*

expertise, i.e., "anything goes" in weighing hazard claims, or adheres rigidly to scientific dogmas of a select few. A more creative and flexible approach to knowledge may provide a fruitful third way.

The hazards field needs more advanced study of the role of knowledge. Useful theories (some covered here) appear in other fields, and the mental models method is flexible enough to include non-technical types of knowledge. Measuring different knowledges held by different people will not be easy. Researchers will have to recognize when people know more than they can say,[81] or grasp the "practical logic" behind new technologies far better than they can answer "direct questions about the nature of scientific inquiry."[82] Further study of the varied nature of ignorance (Figure 1) also would help.

People's relative knowledge (both within and between lay and expert populations) may indeed predict the issues they attend to or worry about, and what they decide to (or actually) do about these issues. Testing that possibility more definitively, whether for laypeople or experts, requires that hazards scholars first admit the depth and nature of their ignorance about knowledge. Only then may we truly begin to learn the degree to which knowledge affects hazard attitudes and behaviors.

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81 MICHAEL POLANYI, PERSONAL KNOWLEDGE: TOWARDS A POST-CRITICAL PHILOSOPHY (1962).

82 Ziman, *supra* note 74.