A REVIEW OF THE PSYCHOLOGICAL LITERATURE ON RISK PERCEPTION IN TERMS OF CHANCE, HARM, AND CONTEXT

By

Bill D. Decker

A THESIS
Plan B Paper

Submitted to
Michigan State University
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Department of Agricultural Economics

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ABSTRACT

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This review examines the psychological literature on risk perception in terms of van Ravenswaay's proposal of a broad-based definition of risk perception that includes the three concepts of chance, harm, and context. The review further investigates the manner in which psychological researchers attempt to measure risk perception. It is suggested that the majority of psychological research on risk perception does not address van Ravenswaay's concepts in a comprehensive manner.

This review of the psychological literature reveals that elements of van Ravenswaay's concepts are often employed as variables by psychological researchers, although not in a fashion similar to that suggested by van Ravenswaay. It is proposed that van Ravenswaay's definition of risk perception would go far toward alleviating much of the difficulty in interpreting and comparing studies from competing disciplines. It is also proposed that the literature reveals serious implications concerning economists' risk perception proxies.

To my parents

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Finally, the greatest thanks must go to my father, John Decker, my stepmother Helen, my brother Pat, and most assuredly, my mother Patricia (I miss you more each day) for their unbounded support.

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Chapter 1: INTRODUCTION

Problem Statement

There are few subjects that are more important to more people nowadays than the controversies over harm to the environment and public health and safety from a variety of natural and human-made sources. Recent shifts in the political climate intensify the need for a more complete understanding of the risks associated with certain activities. Recent legislative efforts to increase the reliance of government agencies on risk analyses and benefit-cost analyses as decision tools can only increase the pressure on experts to provide increased understanding of the risks and benefits associated with human activities.[1] Unfortunately, as risk assessment experts address these needs it is readily apparent that there is a disparity between their assessments or perceptions and those of the public. This disparity can be the source of turmoil for many public policy officials.

Any effective risk management policy or risk communication effort must contend with this disparity. In order to do so there needs to be an understanding of the source(s) of the disparity. There is a wealth of literature that examines the sources of the disparity between experts' and laypeoples' perceptions of risk. Any number of reasons can be cited for the discrepancy, however, these reasons differ across disciplines. Measuring risk perception differs across disciplines and there is no general consensus on the "proper" way

[1] There is an intense effort being put forth in Congress to reevaluate regulatory acts such as the Clean Water Act, and the Endangered Species Act. The proponents of such efforts typically call for all new regulations to be tested in terms of either risk/benefit or cost/benefit analysis.

to perform measurements. Likewise, the characteristics of risk perception differ across disciplines. For example, van Ravenswaay (1994) points out that while psychologists are concerned with determining how people rank risky activities, risk assessment experts are interested in estimating the magnitude of risk related to a specific hazard.

In turn, economists seek to develop estimates of the value of reducing the health risk associated with a wide range of hazards. The most common methods used by economists to estimate the benefits of risk reduction are hedonic, contingent valuation or averting expenditure methods. Each of these methods requires some measurement of the risk reduction people are valuing implicitly or explicitly. Studies employing hedonic or averting expenditure methods typically assume that respondents perceive risks in the same manner as scientists and experts do. Contingent valuation methodology typically proceeds on the assumption that the respondents perceive risks to be the same as the information provided to them within the survey instrument. These assumptions beg the question of whether economists' risk perception proxies are accurate. In all likelihood they are not accurate, as individuals are likely to differ in their evaluation of different risks.

Objectives

The objective of this particular paper is to review the literature on psychological research on risk perception. The purpose of this review is to examine how this research might relate to concepts of risk perception developed by van Ravenswaay. Are elements of van Ravenswaay's three concepts extant and tested in the psychological literature? If they are found in the literature are they significant? Likewise, we are also interested in determining whether a distinction is made between risk perception and risk acceptability in the psychological literature. Finally, what are the implications of psychological risk perception research for economic theory.

Thesis Organization

The rest of the thesis is organized as follows. Chapter 2 introduces the van Ravenswaay definition of risk perception and provides a better understanding of how the three components of the concept are interlocked. Definitions of the terms: chance, harm, and context are provided in this section. Included in this section is a brief discussion of the subtle differences between risk and risk acceptability.

Chapter 3 concerns itself with the development of psychological research on risk perception. This section begins with a brief account of Chauncey Starr's contributions to initial discussions of risk perception through his work with revealed preferences. This is followed by a short introduction to the work of Tversky and Kahneman on heuristics. The chapter concludes with a brief examination of the various ways risk perception is measured in the literature.

Chapter 4 commences with the introduction of the psychometric paradigm. The psychometric paradigm developed out of concerns related to Starr's revealed preferences hypothesis. This section includes discussions of the assumptions and limitations of the paradigm, as well as criticisms of the methodology. Included in this section is an examination of the use of factor analysis within the paradigm. Also included are terse sections addressing accidents as signals, the social amplification of risk, and some of the major modifications of the paradigm over time. A subsection examining psychometric studies in general closes out this section of the paper.

Chapter 5 investigates the psychological literature on trust and outrage. The significance of trust and outrage in explaining risk perception is considered. The section takes a look at the results of two types of studies, one a typical telephone survey, the other a simulation experiment.

Chapter 6 presents the development of mental models as possible tools to explain risk perception. A description of mental models and the steps involved in the methodology are provided in this segment. A subsection explores the implications of considering humans to be intuitive toxicologists. The section concludes with a discussion of how well mental model methodology addresses van Ravenswaay's concerns about risk perception measurement.

Chapter 7 provides conclusions concerning the results of the literature review. It includes a summary of the significance of van Ravenswaay's three concepts in the psychological literature on risk perception. There is a discussion of the implications for economic theory in reference to utility theory and the aforementioned benefit estimation procedures. Finally, it is proffered that van Ravenswaay's broad-based definition of risk perception may be a possible route to the alleviation of much of the difficulty in comparing and interpreting studies.

Chapter 2: van Ravenswaay's Concept of Risk Perception

Chance, Harm, and Context

van Ravenswaay (1995) defines risk perception as an assessment of the chance of harm in a given context. This is very similar to technical definitions of risk. However, the three concepts of chance, harm, and context are multidimensional when measured across individuals. As defined by van Ravenswaay, **chance** is determined with respect to a particular population and time period. According to van Ravenswaay, chance of harm must be expressed in terms of a population over a specific period of time and for a specific hazardous condition or activity by members of the population. For example, there is a big difference between expressing the risk of a disease in terms of annual incidence and lifetime incidence. Likewise, some respondents may believe that different populations are significant for different diseases or events. For example, two respondents may both be thinking about leukemia but one may be worried about a population of adults while the other is thinking in terms of children. It is imperative that risk perception researchers specify or elicit the population, time period, and activity or event that respondents are considering.

Harm denotes the type of harm, its severity, duration, mitigation cost, painfulness, reversibility, immediacy, and lifecycle timing. There can be a variety of types of harm or loss associated with a specific activity, event, or disease. For example, respondents may differ in the types of harm they associate with nuclear waste storage. Some might feel that cancer is the problem, while others may suggest that genetic mutation or nervous system disorders are paramount. The same line of reasoning may be applied to severity, duration, mitigation costs and other facets of harm. If we are to obtain consistent measures of risk perception researchers need to specify or elicit these different dimensions of harm from the respondents.

Context is the unique set of circumstances that results in a specific level of hazard exposure and population vulnerability to harm. van Ravenswaay includes the following under the context heading: extant risk management strategies, the chance of hazards occurring given those strategies, amount of exposure to those hazards, the susceptibility of harm given the exposure, and some level of uncertainty concerning each of the above variables (van Ravenswaay 1994). An example may make this concept easier to understand.

Respondents may take some action to avoid a hazard. For example, food consumers might wash fresh produce or buy organically grown produce to avoid pesticide residues. These risk management strategies alter risks. Even if people take the same action, there may be quite different ideas about how much risk reduction is associated with each action. Going further, there may already be systems in place to deal with the consequences of a particular risk, such as auto insurance. All of these many different facets of context must be specified or elicited to ensure that respondents are assessing the same type of hazard.

van Ravenswaay's review of the risk perception literature points out an important point concerning public perception of risks. It makes a great deal of difference whether people are asked to make general statements about risks or are asked to rate the seriousness of specific hazards. For instance, in her research on agrichemicals, van Ravenswaay found that two very different portrayals of perception can be obtained depending on the question being addressed. When asked open-ended questions about their attitudes toward food safety, few respondents mention pesticides. However, when asked closed-ended questions rating the seriousness of pesticide residues upwards of 80% of respondents rate pesticide residues as serious hazards.

The differing responses to open-ended and closed-ended questions present a quandary. van Ravenswaay presents two possible explanations. First, it is conceivable that using two different types of questions may force respondents to weigh varying circumstances and contexts. The open-ended questions attempted to elicit current food-safety problems. The closed-ended questions carried an implicit assumption that residues existed on or in the food. Additionally, the closed-ended questions made no determination as to the quantity of pesticide involved or which pesticide to evaluate (1995). It is reasonable to assume that responses would have been very different if the questions had completely specified the foods involved, where they were grown, or if residues met federal standards.

The other explanation offered by van Ravenswaay is that at-risk populations were defined specific to open-ended and closed-ended questions. It may be that individuals answering the questions envisioned environmental hazards or hazards to food handlers or harvesters. On the other hand, the open-ended questions created a more specific set of circumstances by asking for assessments of a respondent's personal food safety concerns.

van Ravenswaay (1995) goes on to contend that no matter the explanation for the discrepancy between results from the two types of questions, interpretation of the survey data requires an explicit understanding of what the questions are designed to measure. A clear theory of risk perception must provide the basis for question design. Further, it is imperative that variables that define risk perception be consolidated into question design and that they be held constant or varied, as required by theory and if feasible.

Risk and Risk Acceptability

Before going any further it is important that we understand the often subtle differences between risk, hazard, and exposure and risk perception and risk acceptability. Risk is usually presented as the expected number of deaths per unit of something per years exposed (Covello, Sandman, and Slovic 1991). We also need to make some determination of the population that is involved. For example, we might say that pesticide residues in food is expected to kill 1.4 people in 1,000 out of the population of migrant apple harvesters over a lifetime. In this case risk is the result of a combination of exposure (i.e., the amount of contact, the amount of food consumed, population size) and a hazard, in this case pesticide residue in food. van Ravenswaay (1995) observes that a more commonly accepted definition of risk is the chance of harm in a given context.

van Ravenswaay notes that in any discussion of risk perception it is necessary to distinguish between risk perception and risk acceptability. As defined above, risk perception is an assessment of the chance of harm given a specific context. Risk acceptability centers around the choices individuals must make about managing risks.

Seen in this light, risk acceptability is not some unique number, as with risk assessment, but fluctuates according to the costs of risk management to the individual.

For instance, the perception of risk associated with rock climbing involves what individuals think are the chances of harm or loss from a particular amount of climbing in a specific context. Whether the person decides to go climbing in the face of those risks involves an explicit decision about the conditions under which the risks of climbing are acceptable. In effect, people may not like the fact that climbing imposes a health risk, but they may believe that climbing is enjoyable enough to readily justify spending a certain amount of time hugging the side of a mountain. Thus we can observe that while the two concepts, risk perception and risk acceptability, are closely related they are not one in the same.

Provided in Appendix 2-1 is a list of studies that address one or more of the following: risk perception, benefit perception, and risk acceptability. This list includes the authors' names and a yes or no answer to the question of whether the study deals with the particular concept. Many of the studies reviewed for this paper examined at least two of the three measurements. Only nine studies included all three in some fashion. By far, the most common was risk perception. Not surprising since that is the focus of this paper.
A few of the early studies asked respondents directly about the acceptability of a specific risk or about the desired level of risk (Fischhoff, Slovic, Lichtenstein, Read, and Combs 1978; Fischhoff, Watson, and Hope 1984; Slovic, Fischhoff, and Lichtenstein 1979, 1981, 1982, 1985).

Chapter 3: Psychological Analysis of Risk Perception

Psychological research in the area of risk perception initially concerned itself with studies of probability assessment, utility, and decision making processes of individuals (Cvetkovich and Earle 1992). The literature provides evidence that the earliest discussions of risk perception in a social science framework were initiated over twenty-five years ago by Chauncey Starr's article titled "Social Benefit Versus Technological Risk" (Freudenberg 1993; Renn 1992; and Slovic 1992, and Wildavsky and Dake 1990). Starr was interested in determining how much society was willing to invest or pay for safety. Starr felt that there was no adequate economic or social theory establishing a quantitative measure of benefits relative to costs for accidental deaths due to technological advancements in the public realm. As a result Starr developed his own empirical approach, the revealed preferences method.

Chauncey Starr's Revealed Preferences Hypothesis

Starr's revealed preferences approach hypothesizes that society reaches some optimal equilibrium between the risks and benefits of an activity through trial and error. Starr surmised that by examining historical risk and benefit data on accidental deaths from technological development in the public sector one could uncover underlying patterns of acceptable tradeoffs between risks and benefits. Starr concluded that much of the difference between the "revealed preferences" of society and the, so-called, true risks, or expected death rates, could be explained and predicted by specific risk characteristics, such as individual control over the risk (Freudenberg 1993; Slovic 1992). Later in the review we will find that the rise of interest in qualitative characteristics is directly attributable to Starr's treatment of risk characteristics.

While Starr's research deals with acceptable risk rather than risk perception, it managed to strike a chord with interested parties in other disciplines. Starr's research spawned a lively and spirited debate leading to the emergence of risk perception and risk communication as independent research areas. The initial debate focused on the validity of Starr's assumptions. There was some concern about his reliance on historical data as a predictor of current or future responses to safety concerns. Starr also readily conceded that his use of historical data precluded researchers from determining what might be best versus what was traditionally acceptable. Another point of contention surrounded Starr's assumption that accepted risks were acceptable risks. There were also concerns about the availability of choice in the marketplace and the rationality of decision making (Slovic 1992).

Tversky and Kahneman

Slovic (1992) states in his review of psychological risk perception research that one of the most influential early studies of people's responses to hazards was conducted by Tversky and Kahneman in 1974. What they discovered is that people often employ a set of heuristic rules in an effort to account for the uncertainty which exists in everyday life and to deal with probabilities. Unfortunately, while heuristics may be the result of many years of evolutionary selection, they are by nature very general and may not be adequate to handle the delicate subtleties of a time and age where we can measure chemical concentrations in parts per trillion.[2]

Take, for example, the problems associated with relying on the availability heuristic. This is where the probability of an event or phenomenon is judged by its cognitive availability (how easily it is recalled). This can offer a computational shortcut, but particularly memorable events may be overemphasized while common, less distinct incidents may be underestimated.

According to Slovic, Tversky and Kahneman found that people are resistant to information that is contrary to their original beliefs; contrary information is often deemed unreliable and even false. A similar problem can occur at the opposite end of the spectrum. When the original opinion is weak or even nonexistent, people are very open to suggestion and can be swayed by the way the problem is formulated.

While Tversky and Kahneman may not have been attempting to measure risk perception, their work does apply directly to such attempts. If laypeople are processing information using heuristics it begs the question of whether economists or other researchers are actually measuring what they think they are. If Tversky and Kahneman's contentions are correct then the need for specifying or eliciting the elements of chance, harm, and context becomes even greater.

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[2] There is no guarantee within an evolutionary process that the "best" will survive.

Risk Perception Measurement in the Literature

Researchers attempt to measure laypeople's risk perceptions in different ways. Typically, respondents were asked to rate the seriousness or risk of a particular hazard or group of hazards. Respondents were almost always presented questions along the lines of : "In general how risky (serious) do you consider the following item(s) to be?" In the early efforts of Fischhoff, Slovic, and Lichtenstein, respondents are told to consider the risk of dying as a consequence of the activity or technology and to give the least risky item a rating of 10 and rank the rest accordingly. Respondents are allowed to provide their own scale. For example, if one activity or technology received a ranking of 50 and another received 100 the second activity should be twice as risky as the activity receiving the 50.

A study by Harding and Eiser (1984) employed bipolar continuous rating scales requiring respondents to mark their rating with an X. These ratings were converted to numerical form (0 to 70) by measuring the distance in mm. from the left-hand extreme. The Sparks and Sheperd study measures perceptions of 23 risk "characteristics" which include some measures of risk perception. Appendix 3-1 contains examples of how risk perception is measured in individual studies. Included are the authors of the individual studies, the variables or questions used to measure risk perception as defined by each study, and the scaling method employed by the researchers.

Chapter 4: The Psychometric Paradigm

Concern about the validity of many of Starr's assumptions and other deficiencies prompted psychological researchers to recreate Starr's study using questionnaires asking people directly about their perceptions of risks and benefits and to express their preferences (as with Starr's work, expressed preferences deal with acceptable risk) for a variety of risk/benefit tradeoffs (Slovic 1987,1992). Slovic claims that by using a variety of psychometric scaling methods psychologists have produced quantitative measures of perceived risk, risk acceptability, and perceived benefits. These methods include, numerical rating scales, attitude questions, word association, and scenario generation. This approach and its theoretical underpinnings is referred to as the psychometric paradigm (Renn 1992; Slovic 1992).

According to a review of the psychometric paradigm by Slovic from 1992, the results of early studies show that the concept "risk" means different things to different people. For example, when experts estimated risk in terms of annual fatalities their responses tended to be highly correlated with technical estimates of annual fatalities. In contrast, while laypeople could assess annual fatalities when asked to do so (their estimates were also similar to technical estimates), their judgements concerning risk in terms of annual fatalities were sensitive to other factors as well (e.g., controllability, threat to future generations). Slovic asserts that this sensitivity results in judgements about risk that differ from laypeople's (and experts) own estimates of annual fatalities. Slovic is unclear in his use of the term "differed" in this instance. It is not clear whether respondents are asked to make two different types of assessments or whether their estimates differed over time, etc.

The psychometric paradigm carries with it a set of assumptions and limitations. For example, it is assumed that people have the ability to provide answers to sometimes extremely difficult questions. The results will be dependent on the hazard being studied, the type of questions used and the way material is presented to respondents, and the type of data analysis methods employed by the researcher(s). Perhaps the most important assumption of the paradigm is that risk is subjective. Slovic (1992) goes so far as to suggest that the subjectivity is inherent. Typically, the subjectivity is seen to be the result of the influence of a variety of social, institutional, psychological, and cultural factors.

Another interesting result is that people tend to view current risk levels as unacceptably high for many activities. Slovic contends that the gap between perceived and desirable risk levels suggests that contrary to Starr's assumptions, respondents are unsatisfied with the way that markets and other regulatory tools equilibrate risks and benefits.

From an economic standpoint, the gap between perceived and desirable risk seems logical. A basic assumption of orthodox economic theory is that people desire more of a good. If the reduction of risk is viewed as a good than we would expect people to want a greater quantity and/or quality of that good. In such a case, the question, from an economic standpoint, is whether they would be willing and able to pay for those reductions.

He further complains that there is no systematic relationship between perceptions of risks and benefits. In the case of systematic relationships and the lack thereof, is there reason to expect such relationships to exist? Is it not possible that any relationship between perceptions of risk and benefits is random, or at least, situation-specific in nature? It should be noted that random relationships may exhibit underlying patterns that are difficult to distinguish if relying on modeling techniques of a linear nature.[3]

Activities and technologies have risks and benefits, but there is no relationship between the two per unit of activity or technology. For example, a high-benefit activity may also carry a relatively high risk. Conversely, a high-benefit activity could just as easily carry a relatively low risk. The risk is measured independent of the benefits. Including benefits into the equation brings up questions of acceptability but there is still no reason to expect any kind of systematic relationship.

Factor Analysis

Perhaps the most influential work has been that of Slovic, Fischhoff, and Lichtenstein. Their attempts to quantitatively measure perceived risk hold a prominent position in the literature on risk perception. A great number of studies have employed the basic framework first established by Slovic, Fischhoff, Lichtenstein, and their colleagues.

Slovic, Fischhoff, and Lichtenstein, and their colleagues sought to assess laypersons' perceptions of different hazards with respect to a set of "risk characteristics."

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[3] There are cases of random or seemingly random relationships or equations existing at what has been termed "the edge of chaos" exhibiting underlying systematic relationships. However, these relationships were only discovered through the use of high level mathematics and large amounts of computer power.

Psychological research employs an interesting technique to examine the correlation between the qualitative characteristics of risk across a range of hazards. This technique is known as factor analysis. Research shows that many of these characteristics can be consolidated into small sets of higher order factors (Slovic 1987). Using a four quadrant graph and labeling the x-axis as dread and the y-axis as unknown risk, psychologists have created a factor space which contains point estimates representing perceptions and attitudes concerning risk.

According to Slovic, the most important factor is that of dread. Apparently, the more intensely people dread some hazard the higher is its perceived risk. Slovic points out that experts do not relate their perceptions of risk to any of these characteristics. Instead they tend to associate riskiness with annual mortality. The result of such differences of opinion may be a conflict over risk.

The factor-analytic approach can be found in various forms in the literature. Sparks and Sheperd (1994) apply a version of the factor-analytic approach to the field of food-related hazards. The objective of their study was to secure a structural representation of risk perception with respect to twenty-five potential food-related hazards. They also wished to assess the occurrence of overoptimistic bias.[4] Their goal in this area was to explore the possibility that there are certain food-related hazards that attract this bias and some that do not.

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[4] This is the tendency for people to underestimate their personal susceptibility to risks in comparison to other people's susceptibility to those same risks.

Sparks and Sheperd mailed 800 surveys to members of a consumer panel of a private research corporation in the United Kingdom and received 216 responses (27%). No details were provided concerning the members of the panel. There is no discussion of where the panel was drawn from, if they were ordinary consumers or if they were a hand-picked panel of experts. The returned sample was not representative of the general population. 183 of the returns were women, 31 were men, and two failed to provide their gender. The respondents were given a questionnaire asking them to rate twenty-five potential hazards with respect to twenty-three risk characteristics using 7-point scales. The respondents were asked questions of the following type: "How serious do you think are the disadvantages of these potential hazards?" (1 = "no disadvantages" and 7 = "extremely serious disadvantages"); "When the disadvantages of these potential hazards take the form of ill-health, how likely is it that this will lead to fatality?" (1 = "extremely unlikely to be fatal" and 7 = "extremely likely to be fatal").[5] These characteristics were based on the original nine characteristics utilized by Slovic *et al* (1979).

Sparks and Sheperd employed a principal-components analysis of the mean scores of each characteristic relative to each potential hazard to obtain a three -component solution[6] that accounted for 87% of the variance in their model. They labeled the first

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[5] A complete list of the 23 questions can be found in the appendix of the Sparks and Sheperd study.

[6] A principle component solution can be explained as follows: suppose we have k explanatory variables. We can consider linear functions of these variables:
$z_1 = a_1x_1 + a_2x_2 + \ldots + a_kx_k$
$z_2 = b_1x_1 + b_2x_2 + \ldots + b_kx_k$ etc.
Now, suppose we choose the a's so that the variance of z_1 is maximized subject to the condition that
$a_1^2 + a_2^2 + \ldots + a_k^2 = 1$.
This is called the normalization condition. Without the normalization condition the variance of z_1 can be increased indefinitely. z_1 is said to be the first principal component. It is the linear function of the x's that has

component "severity." This component accounted for 45.3% of the variance. The second component was labeled "unknown" and accounted for 32.5% of the variance. Their third component was entitled "number of people exposed." This component accounted for 9% of the variance. These components provide a three-dimensional model of the risk perceptions associated with food-related hazards that is similar to that of Slovic *et al* (1979).

In order to test for the presence of optimistic bias, the authors employed the Hotelling T^2 test. This test was computed for the ratings of personal risk on all 25 of the potential hazards to ascertain whether the ratings were significantly lower than the midpoint of the scale. This refers to the following survey question regarding the degree of personal risk entailed: "To what extent do you think you are personally at risk from these potential hazards?" (1 = "much less than most people" and 7 = "much more than most people" with "same as most people" as the midpoint).

The authors concluded that there was a significant multivariate effect that indicated comparative optimism ($F(25, 166) = 11.04$ $p < 0.001$). Performing univariate significance tests obtained F values with p-values < 0.001 (or less) for all of the following potential hazards: "food additives, artificial sweeteners, caffeine, alcohol, nutritional deficiencies, bacterial contamination of food, excessive calorie intake, a high-fat diet, BSE,

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the highest variance (subject to normalization).
Maximizing the variance of z (subject to normalization) produces k solutions. Correspondingly, we construct k linear functions $z_1, z_2, \ldots, z_k$. They are called principal components of the x's. They can be ordered so that var $(z_1) >$ var $(z_2) > \ldots >$ var (z_k)
z_1, with the highest variance is called the first principle component and so on down the line. Unlike the x's, which are correlated, the z's are orthogonal or uncorrelated. For a more detailed explanation please refer to an econometrics textbook such as "Introduction to Econometrics" by G. S. Madalla (1992).

food irradiation, microwave ovens, food colorings, vitamin C deficiency, and a high-sugar diet" (p. 802). The authors aver that these results signify that respondents exhibited a tendency to estimate their personal risk as lower than that of most other people for those particular hazards. They further state that "high-controllability" hazards are associated with "optimistic" ratings. Sparks and Sheperd found that the correlation between mean control ratings and mean optimism ratings was relatively high, 0.92, leading them to conclude that optimism increased as respondents believed their ability to control risks increased.

Sparks and Sheperd concluded that while their analysis indicated components similar to those of Slovic *et al* (1979), caution should be exercised. If methods of obtaining characteristics from the respondents were utilized rather than presenting characteristics to them the factor representations could be very different. They further cautioned that they found no indication of the processes leading to overoptimism but the data did show a correlation between control and optimism.

Finally, they noted that the potential hazards did not reflect the same level of specificity or position in a causal network. For example, genetic manipulation refers to a technology, while pesticide residues refers to a particular consequence of technological application; vitamin C deficiency is much less general and less inclusive than nutritional deficiencies. The authors stressed that this variability must be accounted for when interpreting the location of a hazard in the component space. This was seen to require further research into the influence on risk perceptions of how hazards are cognitively represented and the way descriptive language is utilized.

Sparks and Sheperd make an interesting observation that may have some relevance for work being done with mental models. They note that the more general category of food additives was rated as more severe than the more specific categories of food colorings and artificial sweeteners. By comparison, listeria and salmonella were rated more severe than the more general bacterial contamination. They feel this implies a lack of any simple evaluative relationship between general and specific categories. Instead, it is likely to be a complex relationship, which depends on how categories or concepts are presented. This evaluation sounds somewhat similar to the caveats invoked by Bostrom, et al. and Maharik and Fischhoff concerning the direction of the flow between general and specific concepts in the mental model methodology.

Accidents as Signals

Slovic examines the importance of considering indirect costs and damages when analyzing risk. Using the example of ripples on a pond, Slovic makes the point that hazards can create externalities which must be accounted for if predictions of impacts are to be accurate. For example, in some cases only one company may be involved in an incident. In other events, all companies in an industry may be affected. In some extreme cases, businesses, industries, or agencies connected only in a limited manner to the original event may suffer adverse effects. Knowledge of the extent of effects may alter the perception of the risk of the hazard.

Slovic examines the accident at Three Mile Island and observes that while no one died as a direct result of the accident and very few incidences of cancer occurred, there were huge industry-wide effects as a result. Slovic contends that people interpreted the accident as a signal of future events. This can be related directly to the concepts of chance, outcome, and context.

Even though very few injuries occurred, the potential for harm was significant. The specified population that could have suffered was extremely large, witness Chernobyl. The harm was of a severe nature that would most likely result in some form of cancer of a long duration. The context was a set of circumstances which included human error, egregious design flaws, and location, that resulted in a potentially high level of exposure and susceptibility to harm. Of course, each of these elements can be defined more specifically resulting in different perceptions of risk. But this does provide an example of how the three components could be applied to a given situation.

Social Amplification of Risk

There have been efforts to establish a conceptual framework describing how psychological, social, cultural, and political factors interact to amplify risks and create ripple effects. This framework is presented by Renn, et al. (1992), and Kasperson in *Social Theories of Risk* (Krimsky and Golding 1992). The essence of this framework is that what people perceive as a threat is influenced by their values, attitudes, social influences, and cultural identity (Renn, et al. 1992). These researchers conclude that five sets of variables enter into the amplification process: physical consequences, the amount of press coverage, individual layperson perceptions, public responses, and socioeconomic and political impacts (Renn, et al. 1992 and Kasperson 1992). Based on an empirical study of the functional relationships among the five sets of variables listed above, the researchers proffer that perceptions about hazardous events and social responses or mitigating actions are more strongly related to exposure to risk than to the magnitude of the consequences associated with that particular risk (Renn, et al. 1992, Kasperson 1992).

This implies that laypeople consider simply being exposed to some hazard(s) reason enough to warrant taking some action to prevent or mitigate the consequences of exposure. If this is the case, it indirectly leads us to the conclusion that in this particular instance laypeople's perceptions of the risks associated with a particular hazard were greater than those of the experts. In short, it may be that people perceived the risks to be so great that simply being exposed was enough to warrant concern and action. Likewise, rather than saying that individuals are more worried about the possibility of exposure, which is only one part of making a judgement about the risk of some hazard, it could be that the study did not account for all of the possible scenarios of chance, harm, and context that laypeople were taking into account.

The study examined 128 hazardous events. Since our interest lies in risk perception, we will focus our attention on how the study gathered information about respondent's perceptions of risk. What one finds is that procedures in accordance with the psychometric paradigm were followed by the researchers. Respondents were University of Oregon students.[7] Researchers employed standard 7 and 9 point scales measuring respondents' assessments of seriousness, familiarity, and dread along with several new scales. The new scales were to measure assessments of concepts such as

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[7] No details were provided as to the sample size.

perceived managerial incompetence, the assignment of blame, and the preferred way for society to handle the risk to avoid future occurrences of the respective hazard event. Unfortunately, no details were provided concerning the types of questions used to elicit their measurements. However, since the study relied on the use of psychometric paradigm procedures, it is in all likelihood safe to assume that there was little or no effort made to specify the scenarios being assessed by the respondents in terms of chance, harm, or context.

Paradigm Modifications

Slovic (1992) relates that over time researchers applying the psychometric paradigm moved away from the use of students and local citizens groups. International efforts include local populations as well as representative national samples (Englander, et al. 1986, Harding and Eiser 1986, Kuyper and Vlek 1984, Tiegen, et al. 1988, Sparks and Sheperd 1994, Mehta, Dinshaw, and Simpson-Housley 1994, and Hinman, et al. 1993). Researchers in the United States turned to large-scale studies whenever possible. For example, Gould, et al. (1988) studied samples of 1,320 people in New England and the southwestern United States in a replication of earlier Slovic, Fischhoff and Lichtenstein work. Morgan, et al. (1985) questioned 116 alumni of Carnegie-Mellon University concerning their perception of risks from electric and magnetic fields.

Over time the hazard domain has changed dramatically. Early psychometric studies employed large hazard sets containing diverse items such as bicycles and nuclear plants. Figure 4-1 provides a sampling of the many hazards that have been of interest to psychological researchers.

Nuclear power	Motor Vehicles
Handguns	Motorcycles
Smoking	Alcoholic Beverages
Police work	General Aviation (Private)
Pesticides	Fire Fighting
Surgery	Large Construction
Hunting	Commercial Aviation
Spray cans	Electric Power
Mountain Climbing	Swimming
Bicycles	Contraceptives
Skiing	High School and College Football
X-rays	Railroads
Food Preservatives	Power Mowers
Food Coloring	Prescription Antibiotics
Home Appliances	Cigarette Smoking
Vaccinations	Artificial Sweeteners
Asbestos	Aspirin
Herbicides	Solar Power
Tranquilizers	Hydroelectric Power

Figure 4-1 List of Hazards of Interest to Psychological Researchers

Changing the Hazard Domain

This practice generated the question of whether factor analysis of a more restricted set of hazards, all falling within the same general category, would alter the expected results. For example, Kraus and Slovic (1988) examined railroad collisions in detail. At first glance, this study seems to come tantalizingly close to incorporating van Ravenswaay's concepts of chance, harm, and context. Closer examination reveals a number of shortcomings.

Using an analysis of hazards associated with the German railway system, a set of 49 railroad hazard scenarios were constructed. Each scenario included the following components: the type of train involved, the type of cargo, the location of the train at the time of the incident, the type of accident, and the cause of the accident. This goes far toward specifying the components of context and chance but still comes up short in the area of harm. Context, as stated earlier, is the unique set of circumstances that result in a specific level of hazard exposure and population vulnerability to harm. The 49 scenarios provided to respondents seem to do an adequate job of addressing that requirement. Turning to the concept of harm we find that the only survey question addressing this component asks respondents about the catastrophic potential of the particular scenario. There is no attempt made to determine what type of harm or loss respondents were associating with each scenario. Some of the respondents may have been thinking of different types and severity of harm.

For instance, take the scenario of a traditional train (not a high-speed "bullet" train or urban rapid-transit system train) carrying passengers on open ground that derails as the result of human error. There are a variety of injuries, mitigation costs, levels of painfulness, etc. that could be associated with such an accident, i.e., deaths, injuries requiring long periods of recovery, minor scrapes and bruises, etc. and we need to know the different dimensions people had in mind when responding to the questions. As for the concept of chance, the study does provide specific scenarios regarding whether passengers are on board and the time and location of an accident. Even though the study does not coincide completely with van Ravenswaay's concepts, it does bear out the contention that representing diverse hazards as a single, homogenous category may be misleading as a predictor of response to specific hazards. It may be very important for policy makers and system designers to know that there are substantial differences in the degree of concern people exhibit for a freight train derailment and the concern for derailment of a passenger train. Likewise, it is equally important for researchers to understand that people view individual hazards differently when attempting to measure risk perception.

Psychometric Studies in General

This review includes numerous articles and studies that either employ or discuss the use of the methodology introduced by Slovic, at al. (1979,1982). All of these exhibit the same types of discrepancies in terms of comparison to van Ravenswaay's concepts. In general, they address only bits and pieces of the concepts of chance, harm, and context. While they do attempt to go beyond a technical evaluation of the risk they are not diligent in specifying or eliciting populations beyond asking about personal risk and the risk to future generations. Typically, they do not attempt to discern whether respondents are concerned about their neighbors, their communities, children, the elderly, etc. The concept of harm receives the same type of treatment. The overwhelming majority of articles relied on an assortment of specific and general types of harm without addressing their differences.

The concept of context does seem to have a place in the psychometric method. For example, there is ample documentation of the importance of "contextual" variables for shaping individual risk estimation and evaluation (Cvetkovich and Earle 1992; Flynn, Slovic and Mertz 1994; Freudenberg 1993; Hohenemser and Kasperson 1982; Renn, et. al. 1992; Renn 1992; Shrader-Frechette 1991; Slovic 1992; Sparks and Sheperd 1994). However, the use of the term context in this instance is not the same as van Ravenswaay's use of the term. What psychological researchers define as contextual variables include (Hohenemser and Kasperson 1982; Renn, et. al. 1992; Renn 1992; Shrader-Frechette 1991; Slovic 1987, 1992) :

- the expected number of fatalities or losses
- the catastrophic potential
- the beliefs associated with the cause of the risk
- qualitative risk characteristics which include:
  dread with respect to consequences, personal control over magnitude or probability of the risk; the familiarity with the risk; the potential for allocating blame for the risk; the equity of the distribution of risks and benefits; and the immediacy of the consequences.

Examining the above list of variables reveals that what psychological researchers term context includes elements of the three concepts of chance, harm, and context. For example, the expected number of fatalities or losses involve the concepts of chance and harm rather than context. The catastrophic potential, dread, and immediacy of the consequences would be included under the heading of harm. Personal control over the risk, familiarity with the risk, the equity of the distribution of the risks and benefits would be defined as elements of context within the van Ravenswaay concept. Figure 4-2, below, gives an approximation of the way many of the qualitative variables employed by psychological researchers could be categorized as elements of chance, harm, or context. The reader should keep in mind that the three concepts are multidimensional and that many of the characteristics could be placed in more than one category.

The literature points out quite readily that people rely on more than a single factor or characteristic to determine their perception of risk. It appears that most people perceive risk as a multidimensional phenomenon that cannot be fully realized as simply the product of probabilities and consequences (Renn 1992). In other words, there is more to risk than just the expected number of deaths. While there is evidence that the variables are included in the van Ravenswaay definition of risk perception, they are not recognized as contextual variables in the same way as van Ravenswaay would define them. Even so, it does not require much effort to consolidate them into van Ravenswaay's idea of risk perception

Chance	Harm	Context
Low risk to future generations, How many affected	Dread, Catastrophic, Consequences fatal, Individual, Easily reduced, Effect delayed, Chronic, Continuous, Costly to avoid, Disastrous, Dangerous, Poisonous	Control, Equitable, Decreasing risk, Voluntary, Observable, Unknown, Newness, Natural, Necessary, Responsible for protection, No benefits

Figure 4-2 Categorization of Qualitative Variables

The main point of contention is that care is not taken to establish as exact an idea of the respondents' thinking as possible. In short, it is not at all certain that respondents are answering the questions researchers think they are. Interestingly, Slovic (1992) mentions this as an early criticism of the methodology. He states that "a number of methodologically sophisticated researchers have criticized this work for providing the characteristics of perceived risk to respondents, rather than letting the respondents provide them..." (p. 137). This complaint provides a direct connection to the development of mental models, a subject discussed in a subsequent section of this paper.

Chapter 5: Risk Perception, Trust, and Outrage

The issues of trust and outrage are seen as possible explanations for public versus expert risk conflict (Sandman, Miller, et al. 1993; Kasperson. Golding, and Tuler 1992; MacGregor, et al. 1994; and Slovic 1993). Kasperson, Golding, and Tuler suggest social distrust as a factor in the siting of hazardous facilities and risk communication. Their review of several contentious debates between laypeople and industry experts over the siting of hazardous facilities led them to surmise that there has been a broad-based loss of trust in the leaders of major social institutions as well as in the institutions themselves. Further a growing public concern over health, safety, and environmental protection has accompanied that loss of trust. Finally, they observe that both of these processes interact and reach particularly intense levels during debates about the siting of hazardous facilities.

Trust in Risk Management Agencies

MacGregor, et al. (1994) examined the trust in risk management agencies involved in the transport of radioactive waste transport through Oregon. They conducted a telephone survey of 1,006 households in Oregon from three sampling areas: households in the four impacted counties within 10 miles of the transport corridor, households in the four counties, but not within 10 miles of the transport corridor, and households not in the impacted counties.

Respondents were asked to relate their degree of trust in a number of organizations either directly or indirectly involved in nuclear waste transportation. The survey used 10 point scales (1= no trust and 10= complete trust). They obtained the following results: environmental activist groups received the highest mean rating of 6.3, radioactive waste transport drivers received a mean rating of 5.51, state and local government officials received a mean rating of 5.59, nuclear regulatory agencies received a mean rating of 5.31, U.S. Department of Energy and federal government officials received ratings of 5.09 and 4.68, respectively, while the lowest rating, 3.79, went to the industries producing the waste. These results do provide evidence of the need to capture information about the "baggage" or indigenous knowledge that respondents bring with them when researchers attempt to elicit information concerning their perceptions of risk. Unfortunately, details concerning the actual survey were not included in the article. This precludes any comparison to van Ravenswaay's concepts of chance, harm, and context.

Hazard and Outrage

Sandman, et al. (1993) employs a different terminology in their discussion of the public versus expert risk conflict. They proposed the labels "hazard" and "outrage" in reference to, respectively, the technical and nontechnical aspects of risk. In this terminology, hazard is the product of risk magnitude and probability, whereas outrage is some function of whether people trust authority or feel that control over risk management is shared with the affected communities (p. 586). (The reader should note that this is different from van Ravenswaay's use of the term "hazard." In her use of the term, it is seen to be a component of risk, as in the following equation: risk or the probability of harm = hazard x exposure.) The authors contend that outrage is the predominant factor in determining the public's response to risk.

According to the Sandman, et al. work, the typical approach of asking respondents to rate the riskiness of hazards and then to rate those same hazards on several other attributes thought by investigators to be related to perception does not address the social context in which risk judgements are made. Further, they contend that because such factors as trust, power-sharing, respect for community concerns, promptness and completeness in distributing information, etc. are not characteristics of a hazard they are difficult to study using a riskiness rating methodology.

The study relies on experimental research involving simulation to study what they term situational variables (listed above). These variables would all fall within the van Ravenswaay concept of context. The researchers attempted to create hypothetical hazard situations that would elicit risk judgements similar to those from actual hazards (note, we are still employing Sandman's terminology concerning a hazard). The article reports on three separate studies.

The first study used two mock newspaper stories; one dealing with the discovery of barrels of chemicals in a community, the other dealing with plans to build a hazardous waste incinerator. In each scenario, a government agency, rather than a private corporation, was responsible for dealing with the issue. One version of each story presented the agency as willing to share information, encouraging members of the community to form their own opinions and acknowledging that there was some small risk. In the alternative version of each story, the agency was just the opposite. There was an unwillingness to provide some types of information, they released some facts only after repeated requests, and they suggested that community members had no reason to be concerned. While both versions of the stories are reported to have contained the same information about the risk itself, details about the information provided to respondents was not provided within the article.

The questionnaire used 6 point scales for questions about the seriousness of the risk (1= no risk at all and 6= very serious risk). Four-point scales were utilized for questions of trustworthiness (1= very trustworthy and 4= not trustworthy at all) and questions asking whether agency spokes people appeared to be withholding information (1= definitely is and 4= definitely not). A fourth question presented respondents with a list of words describing how one might feel if he or she actually lived in the community presented in the stories. The list contained the following: angry, helpless, frightened, safe, alarmed, relieved, concerned, pleased, confused, and annoyed (p. 587). Respondents were allowed to choose as many terms as applied to the situation. A final question on the incinerator questionnaire inquired whether the incinerator should be built (1= definitely yes and 4= definitely not).

The questionnaires were presented to adult residents of single-family homes in East Brunswick, New Jersey. East Brunswick is a community of middle-income to upper-middle-income residents. Respondents who agreed to participate were given two news stories, one on the barrels and one on the incinerator. 83% of the houses visited had a resident at home who agreed to participate. 71% of those volunteers returned the questionnaires, a net response rate of 59%. A total of 86 questionnaires were returned.

Analyses of the variance in the data on seriousness, trustworthiness, and secrecy were performed for each story separately using the variables outrage (high or low) and story reading order (first or second). The author's report that story reading order showed no main effects or interactions with outrage. As hoped, the two stories about barrels of chemicals produced drastically different perceptions of agency trustworthiness and secrecy. They also report that the perceived seriousness of the risk was only marginally greater in the high outrage condition ($p < .08$[12]) for the two barrels stories. The authors relate that the stories concerning incinerators were less successful in manufacturing different ratings for trust, etc. and yielded no significant difference in perceived seriousness. The correlations between trust and perceived seriousness were .61 for the barrels stories and .62 for the incinerator stories (both p's < 0.0001). The correlations between perceived agency secrecy and perceived seriousness were .53 for the barrels stories and .63 for the incinerators (p's < 0.0001).

Because there was not a strong effect on risk perception in the first study a second study was conducted. The authors presented two possible explanations for the results from the first study. First, the differences between the two stories were too small to show the impact of outrage manipulation. Second, they surmised that respondents may have adopted an atypically rational orientation to the task by looking back at the articles and examining only those sentences directly relevant to the risk. Interestingly, where these psychologists believe the respondent's behavior to be atypical, economists assume a rational response.

The second study only used the barrels of chemicals story, as it had been more successful in creating different perceptions of trust and openness. The questions were unchanged from the first study, but the checklist of emotions was reduced to only the choices of angry, frightened, safe, concerned, annoyed, and alarmed. This time respondents were not allowed to review the stories and were asked to return the questionnaire immediately rather than returning them by mail. The stories were revised to increase the differences between them. In the first study, "outrage" was operationalized only in terms of the agency behavior the researchers thought likely to evoke an outraged response. In the second study, the high outrage version of the story presented respondents with a decidedly outraged community. The high outrage version employed what the researchers viewed as typical person-in-the street interviews to exhibit community outrage. The authors report that the results from this study revealed that when the agency was portrayed as untrustworthy and secretive and the community was revealed to be outraged the respondents rated the risk as more serious.

In the third study the authors manipulated outrage variables, the seriousness of the risk itself, and the amount of technical detail provided in the stories. This time news stories about a perchloroethylene (PERC) spill were utilized. The seriousness of risk was manipulated by varying the estimates of toxicity, the estimated exposures, and the number of people exposed. The high-seriousness condition was approximately five orders of magnitude greater than the low-seriousness case. The technical detail was manipulated by the addition of several paragraphs of information on exposure pathways and toxicological studies. The authors recount that the manipulation of outrage was more extreme than in the first study but less so than that of the second. This was in response to contention that the scenario in the second study was somewhat less than realistic. This time the study focused on the extent to which agency behavior and community outrage increase laypeople's risk perception of low-risk events and the extent to which altering technical details decreases people's risk perception of low-risk events.

Using 6-point scales, respondents were asked: "what is your impression of how serious this situation is?" "How detailed was the information in the story about the health effects of the PERC spill and the ways people might get exposed?" "How appropriate was the Department of Environmental Protection's handling of the PERC spill?" Questions concerning response variables included: "If you lived in the area, how worried would you be about the risk from the PERC spill?" "How important do you consider the risk posed by this situation?" ; and "If you lived in the area, how willing would you be to spend $500 to have your water tested for PERC after the spill?" The sample for this study included 595 New Jersey residents over 18 years of age from middle-income areas in Middlesex county. Again, all respondents were asked to return the story before completing the survey.

Study Results

The authors report that as they had predicted, outrage had a small, but significant, effect on perceived risk ($p < 0.01$). They also found that outrage did not have a significant effect on individuals intention to test for PERC. (The mean response for intention to test was 3.36 with a s.d. of 1.81 on a six-point scale.) They relate that there was a small, but significant effect of outrage on the perceived detail variable. They found that people who read the high-outrage stories judged that they had significantly less technical detail than subjects who read low-outrage stories ($p < 0.01$). Interestingly, they also found that there were no significant effects of the technical detail manipulation. They suggest that perhaps outrageous agency behavior makes people distrust the technical detail provided by the agency, or distracts them or perhaps makes them require more information and detail than if the agency had been more responsive.

As for the seriousness of risk manipulation, they found that the mean ratings for the serious risk variable were only marginally higher than in the low-seriousness condition. They state that the difference between the means was less than a third of a standard deviation ($p < .0001$). Based on the results obtained from two pilot studies where respondents accurately reported exposure, toxicity, and related factors to be higher when they were in fact higher, the authors suggest that the small effect of manipulated seriousness on perceived seriousness is probably not due to a failure to detect the manipulation. They feel that this lends credence to the belief that people tend to see risk as more than the outcome of such factors as exposure and toxicity.

Regression analyses for the perceived risk and intention to test variables exhibited significant multiple correlations between response measures and predictor variables. The authors incorrectly state that the strongest <u>relationship</u> was that for perceived risk (adjusted $R^2 = .25$, $p < .0001$) (p. 594). ^{2}R is not a measure of relationship but is a measure of goodness of fit. R^2 must be between 0 and 1, with a higher value indicating that more of the variation of the dependent variable can be "explained" by the independent variable(s). Obviously, this is not a very strong fit; plainly there are many factors other than those measured by the study that affect perceived risk. They report that the goodness of fit for intention to test was even weaker (adjusted $R^2 = .14$, $p < .001$).

The strongest predictor of perceived risk was a variable labeled societal risk aversion (approximately 7% of the variance, $p < .001$), followed by a variable labeled perceived appropriateness (4% of the variance, $p < .001$). Societal risk aversion was derived by adding the ratings for items measuring that dimension. Respondents were asked about their agreement with two statements: "The public has the right to demand zero pollution from industry" and "An industry that pollutes should not be allowed to stay open, no matter how little pollution it produces" (p. 592). Perceived appropriateness was derived by asking the following: "How appropriate was DEP's handling of the PERC spill?" (p. 591)[8].

Variables denoting outrage and technical detail made no significant contribution to explaining the variance in perceived risk, even though their respective manipulation checks did. The term manipulation check refers to the alteration of the seriousness of the situation, the level of outrage, and the level of technical detail from story to story. The check is a variable derived by questioning respondents concerning their impression of the seriousness of the situation, how detailed was the information about health effects and exposure in the story, and appropriateness of the way the agency handled the situation. Dropping the two checks produced no change in the effect of technical detail. Outrage, however, became a significant predictor ($p < .05$). Even though outrage became statistically significant it remained a very weak predictor of risk perception.

Obviously, the results of the three studies show that while outrage is statistically significant it does not carry any overwhelming effect on risk perception. The first study

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[8] Researchers relied on the same type of six-point scale for all questions in their survey.

found a weak relationship for one story but none for the other. The second study, using a larger sample and exaggerating the differences in the scenarios, exhibited somewhat stronger relationships between manipulated outrage and perceived seriousness. The third study's regression analysis shows that outrage is not a strong predictor of risk perception.

The authors point out three caveats concerning their use of hypothetical newspaper stories. First, using more personal information vehicles may provide different results. As with, van Ravenswaay's concept of context, where and how people attain information needs to be specified or elicited. A change of settings may alter the way an agency conveys its responsiveness. For example, whether people obtain their information at a public hearing or by telephoning an agency may affect the way that person views the agency's responsiveness.

Second, the news stories were hypothetical. The respondents were asked to imagine that the stories had appeared in their local newspapers. Even though efforts were made to generate stories that were very similar to real life, it is impossible to know whether the respondents would respond in the same fashion if the stories were real and had actually occurred in their home communities. A final caveat addressed the fact that many real hazard situations take days, months or years to develop. The test simulations reduce development into materials that only take a few moments to read. The authors also note that while they treat outrage as a single variable, it is actually made up of a variety of factors that may deserve separate examination.

All of the above caveats relate directly to van Ravenswaay's call for a broader definition of risk perception. If we are to obtain an accurate picture of not only what people perceive the risk of a hazard to be, but how they reached that judgement, greater care must be taken to ascertain the specific situations respondents are judging.

Chapter 6: Mental Models

The ability of factor analysis and multidimensional scaling to synthesize thousands of judgements into a few visual displays is accompanied by an ever-present weakness, a lack of depth. Many questions remained unanswered and over time psychologists grew interested in how individuals come to understand the physical, chemical, and biological processes that dictate a hazard's creation and control. The result of this burgeoning interest is the attempt to characterize individual's mental models of hazards. Mental models are defined as a set or sets of principles from which people obtain predictions about a hazard's behavior (Bostrom, Fischhoff, and Morgan 1992). This relates directly to the work of Tversky and Kahneman, in that mental models are representations of the causes of risk perception rather than ways of measuring risk perception. In essence, researchers attempt to determine what people know and need to know about the underlying physical, chemical, and biological processes. Knowledge of what people know and need to know would allow risk communicators to focus on those vital facts that people do not already know.

The mental model approach is based on the use of influence diagrams. In an influence diagram, a form of directed network, each node-link-node combination portrays an influence, in that beliefs about the concept lying at the beginning of a connection affect beliefs lying at the end of the connection. When the diagram is completely specified each influence can be fitted with a conditional probability distribution. Complete specification may be next to impossible. Instead researchers hope that people understand the directions of the influences in the diagrams. In principle, influences might represent opportunities to reduce or increase risks. These opportunities would be included as van Ravenswaay contextual variables. For example, Bostrom, et al. present an expert influence diagram for radon risk in a house with a crawlspace (p. 88) in their study of radon. If an individual's beliefs could be thought of as deviations away from some expert influence diagram, risk communicators may have some basis for determining what information to convey.

The Four-Step Process

Attempting such a strategy requires a four-step process: 1.) the creation of an expert model or influence diagram, 2.) elicitation of individual's beliefs, 3.) mapping those beliefs into the expert model, 4.) constructing communication guidelines based on the gaps and misconceptions between the expert and lay models (Bostrom, Fischhoff, and Morgan 1992 and Maharik and Fischhoff 1992, 1993)

The expert model is a qualitative depiction of physical phenomena that can create risk to individuals. Maharik and Fischhoff (1992) point out that this type of modeling is strictly qualitative and assert that efforts to quantify these beliefs does nothing more than move researchers into regions where disagreement among experts is already common and opens the door to increased lay skepticism about expert claims. The Maharik and Fischhoff studies (1992, 1993) of the risks of nuclear energy sources in space employ an expert model using 113 concepts (79 exposure and 34 effects). The concepts are classified into five separate categories of physical processes and two levels of detail. Bostrom, Fischhoff and Morgan's study of radon risks utilized an expert model containing 71 concepts. These concepts were classified in a method very similar to that of Maharik and Fischhoff.[9]

In order to elicit individual's beliefs a two-stage survey process is used. In the first, or non-directive, stage respondents are asked a series of open-ended questions. These questions usually begin with "tell me what you know about the risk of ..." (Bostrom, Fischhoff, and Morgan 1992, De Marchi 1991, and Maharik and Fischhoff 1992). Once spontaneous responses appear to be exhausted respondents are asked to elaborate on their previous comments. Following this they are asked what they know about major aspects or the processes of the specific risk in question.

During the second, or directive, stage, respondents are asked to sort through a set of photos according to each photo's relevance to the topic. Respondents are also asked to describe the photo and to relate the reasons for their choice of category. The last questions in this section are usually closed-ended attitude and demographical questions. It was hoped that using the photos would increase the chances of evoking untapped beliefs. Bostrom, et al. (1992), report that subsequent work used closed-ended questionnaires which were more easily administered.

For example, Maharik and Fischhoff (1992) asked respondents to evaluate the use of nuclear energy in space on three seven point attitude scales. Respondents were asked whether they favor the use of the technology (where 1 = completely favor and 7= completely oppose, mean of 5.43 and s.d. of 1.52), believed that the technology could be

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[9] A visual representation of the expert influence diagram can be found in either Maharik and Fischhoff (1992) or Bostrom, et al. (1992).

made sufficiently safe (where 1 = definitely can be made safe enough and 7 = definitely cannot, mean of 4.93, s.d. of 1.91), felt that the technology was currently unsafe (where 1= definitely safe enough and 7= definitely not safe enough, mean of 5.67, s.d. of 1.15). It should be noted that the respondents in this study were activists engaged in peace and environmental efforts. It is also likely that the first two attitude scales are eliciting information about risk acceptability and context rather than risk perception.

The third step in the process involves coding the responses. This is a process where two interviews are mapped separately into the expert model by two to three researchers. In the Maharik and Fischhoff (1992) study the coders agreed 70.3 % of the time. Coders agreed 75 % of the time in the Bostrom, et al. (1992) study. In each case, disagreements were ironed out and adjustments were made to the coding scheme. All the remaining interviews were then coded using the agreed upon procedure.

The results of the studies were very different from one another. On average, the respondents in the Bostrom, et al., research generated 14 concepts in the nondirective section where they were asked a series of open-ended questions about their knowledge of the risk. 15 concepts were generated in the directive section where the respondents were asked to sort through the photos. 37 % of the concepts in the directive section were restatements of concepts from the directive section. The mean number of misconceptions about radon was larger in the second section, 2.52 ($p < 0.001$) against .67 ($p < 0.001$) for the first section (Bostrom, Fischhoff, and Morgan 1992). By comparison, the Maharik and Fischhoff study of nuclear energy in space obtained an average of 40.5 concepts for the open-ended segment and 21.4 concepts for the photo-sorting segment. In the second segment, 72% were restated concepts from the first segment.

Statistical Measures

Four statistical measures are used to portray the extent of agreement between the respondents' mental models and the expert model. Completeness is defined as the proportion of expert concepts mentioned by a respondent. This only measures what both sets of researchers call correct concepts. Concurrence is the percentage of respondents' concepts that were in the expert model. Accuracy is obtained by multiplying completeness and concurrence. This results in higher scores for those who not only provide correct concepts but also many of them. Finally, specificity is the ratio of specific, or lower level concepts, to general, or higher level, concepts. A ratio larger than 1 means that the respondent has a higher proportion of specific concepts than did the expert diagram.

In general, both studies report that lay people have a greater grasp of general concepts than of specific concepts. They also find that there was greater knowledge of exposure processes than effects processes. This is equivalent to saying they have a greater grasp of some elements of context than they do elements of harm. In the case of radon, respondents' understanding was judged to be both incomplete and incoherent, in that they included scattered and inconsistent items. It is believed that this could lead to a messy situation where inferences are quite sensitive to the manner in which problems are posed (Bostrom, Fischhoff, and Morgan 1992). This is essentially the same as saying that the made sufficiently safe (where 1 = definitely can be made safe enough and 7 = definitely

respondent in measuring risk perception.

Maharik and Fischhoff contend that their results clearly point out the need for the clear definition of concepts, the filling in of knowledge gaps, the correction of significant misconceptions, for communications to link concepts to one another, and to address peripheral concepts that might be confusing or misleading (Maharik and Fischhoff 1992). This assertion lends credence to van Ravenswaay's belief in the need for a more detailed examination by researchers of the specific scenarios being judged by the respondents.

Intuitive Toxicology

Another, very similar type of mental model approach is developed in a study by Kraus, Malmfors, and Slovic (1992) about the extremely negative perceptions laypeople have about chemical technologies. Most industry and risk management experts find these perceptions difficult to understand. Why, especially in light of massive efforts to assess the dangers inherent in exposure to a chemical substance and the establishment of massive regulatory systems to protect public health, do people in many industrialized nations feel increasingly vulnerable to the risks from chemical technologies? Is it because people fear the technologies or because they do not trust the scientific community? Regulatory agencies are often caught between the proverbial rock and a hard place. Regulatory agencies must contend with both a fearful public and frustrated technologists and industrialists.

Kraus, et al. (1992) approach the problem of differing perceptions from, what they term, an "intuitive toxicology" perspective. They assert that human beings have always been intuitive toxicologists, relying on our senses to detect harmful products or food. Their objective is to explore the cognitive models, assumptions, and inference methods people use to develop an intuitive toxicological theory and to compare them with the cognitive models, assumptions, and inference methods employed in scientific toxicology and risk assessment. This is very similar to the fundamental analysis of the Bostrom, et al. (1992) and Maharik and Fischhoff (1992, 1993).

The study initially identifies some fundamental principles and judgmental components within the science of risk assessment. They developed questions based on these fundamentals in order to determine the extent to which laypeople and experts share the same beliefs. The questions addressed the following areas of concern:

Category 1: Dose-response sensitivity
Category 2: Level of trust in animal and bacterial studies
Category 3: Attitudes toward chemicals
Category 4: Attitudes toward reducing chemical risks (p. 216).

A single questionnaire was designed for both experts and the public. The authors defined the term "chemicals" as including "... all chemical elements and compounds, including pesticides, food additives, industrial chemicals, household cleaning agents, prescription and nonprescription drugs, etc." (p. 216). The questions were designed based on a set of assumptions the authors held about the way respondents might respond.

For instance, perhaps the guiding principle in toxicology is that the dose makes the poison. This means any substance can cause a toxic effect if the dose is strong enough.

Even water can be dangerous to your health if you drink enough of it at once. Therefore, it was suspected that experts would be more sensitive to dimensions of exposure and dose than laypeople. On the other hand, they surmised that the public would adopt an "all or none" point of view concerning toxicity. The authors also believed that laypeople tend to view natural substances as less toxic than human-made substances. Additional hypotheses include the presumption that experts would have a more favorable view of animal studies, that laypeople would exhibit far more negative attitudes toward chemicals than experts, and that laypeople are more apt to want reduction and even elimination of chemical risks.

The study's sample of experts was obtained from the 1988 membership directory of the Society of Toxicology (SOT). The members were segregated according to the type of organization they were affiliated with: academic, regulatory, or industrial. A random number generator selected 120 names from each group. 360 questionnaires were mailed and 170 were returned. The subgroup response rates were consistent with the overall return rate (academic, 44%; regulatory, 48%; and industrial, 49%).

The general public sample was drawn from the Portland, Oregon area. Using a professionally obtained sample screened for a minimum household income of $20,000 and 1,100 households were selected to receive mailings. 262 usable questionnaires were returned out of approximately 975 delivered questionnaires. The respondents were generally not representative of Portland's general population as 58% (versus 48.6% in the population) of the respondents were male; 95.7% high school graduates and 23.1% with graduate-school training (versus 78.7% and 9.9%, respectively, in the population); and

24.6% of the sample had household incomes greater than $50,000 (versus 5.5% in the population).

Even though significant differences were expected between the responses of the two groups there was significant agreement on one question in particular. When asked whether or not they agreed with the following statement: "I think I should know as much as I can about the chemicals around me. The more I know, the more I can control the risks that these chemicals pose to my health and to the environment."; 94.6% of the experts agreed or strongly agreed and 93.4% of the public agreed or strongly agreed. It seems that there may be a common bond among the two groups in terms of motivation to understand and control chemical risks.

Survey Results

The results of the survey lend credence to the assumptions held by the authors. In the dose-response category the public was more likely to concur that exposure to a toxic chemical makes one likely to suffer adverse health effects; that exposure to a cancer-causing agent makes one likely to develop cancer; that the act of being exposed to a pesticide is of more importance than the amount of exposure; that reducing the level of concentration of a potentially hazardous chemical in drinking water would not reduce the danger associated with drinking the water; and that there is no safe level of exposure to a carcinogen. However, we should note that while these views are more common among the public than among the experts, they were not always held by a majority of the public. There was also a large number of laypeople (17.2%) who marked "don't know" or "no opinion" in reference to the question of whether exposure to a carcinogen implies a better chance of developing cancer.

On the question of trust in animal studies there was relatively little disagreement between the public and experts. Both samples were evenly divided over the question of whether animal reactions to chemicals are reliable predictors of human reactions. Approximately 41% of the experts and 46% of the public disagreed with the claim of predictive reliability. Likewise, both groups disagreed with suggestions that proper animal studies could identify all possible harmful effects of chemicals and that laboratory studies could allow accurate predictions about the levels of exposure necessary to cause human harm. One very interesting result came in response to the proposition that when a study produces evidence that a chemical causes cancer in an animal that we can be reasonably certain that the chemical will cause cancer in humans. Experts confidence fell from 55.4% to 40.6%, when compared to the results of the question concerning predictive reliability. In turn, the confidence of the public rose from 43.7% to 69.4%. The public response seems a bit incongruous. Even though they were fairly uncertain, as a group, about the reliability of animal reactions, if an animal developed cancer they strongly believed that it implied that humans would develop cancer as well. One possible explanation may be that respondents were responding in a precautionary manner. Even if they didn't think animal reactions were good predictors it was best not to take a chance, especially if there was evidence that the animal's cancer was caused by a chemical.

Given the above results, the authors felt reasonably certain that the public carried a more negative attitude toward chemicals and would be more apt to want to reduce risks associated with chemicals. In fact, a majority of the public respondents agreed that we have only perceived a very small portion of the risks from chemicals (83.9%) ; that contamination is greater now than ever before (88.4%) ; that chemical risks are very frightening and they don't like to think about them (84.0%) ; that it can never be too expensive to reduce the risks associated with chemicals (61.6%). The public respondents also disagreed with assertions that people are unnecessarily frightened about small amounts of pesticides in groundwater and food (68.7%) ; and that people worry unnecessarily about chemicals (87.1%) . Further, a large number, though not a majority, agreed that they do everything they can to avoid exposure to chemicals and chemical products (40.0%) , and agreed that all use of prescription drugs (17.2%) and chemicals must be risk-free (29.3%) .

Finally, the authors' belief that the public has more confidence in natural substances was upheld. The public also held a more favorable view of chemicals if they came in the form of prescription drugs. They were also more likely to recognize the risk from a prescription drug is dependent on dose than to recognize dose dependence for chemicals in general. Interestingly, 15.8% of the public respondents disagreed with the statement that a 1 in 10,000,000 lifetime risk of cancer from taking a particular prescription drug is too small a risk to worry about. There was considerable disagreement among both toxicologists and the public about whether pesticides are more harmful than fertilizers. The toxicologists agreed with the statement more often than the public did and the public respondents generated many more "don't know" responses.

A rather interesting set of results was received for a question concerning the use of microorganisms as indicators of human responses to chemical exposure. Toxicologists almost unanimously disagreed (89.6%) with the statement that microorganisms are reliable indicators of human response. 55.4% of the public respondents disagreed but a large number, 34.9% answered that they didn't know or had no opinion. These results are interesting because momentum is increasing to reduce the use of animals for testing purposes in favor of relying on computer simulations and microorganisms instead.

Kraus, et al. also carried out a separate analysis to test some alternative hypotheses. They examined the relationship between dose-response views and attitudes toward chemical risks and trust in animal testing. The effects of demographics were also investigated. The relationship between dose-response and attitudes was analyzed at the individual level. The items in each of the four categories were assigned scores based on a four-point scale (1 = strongly disagree, 2 = disagree, 3 = agree, and 4 = strongly agree). All responses in the public sample were scored and the scores were summed across all items in each category to obtain four scale scores per person where a high score represents high sensitivity to dose, high trust, a pro-chemical view, and the acceptance of some degree of risk from chemicals. The authors computed the correlations between scales for each person. The results suggested that those people who felt that exposure and dose moderate chemical risks were more likely to have favorable attitudes toward chemicals and relatively less concern about chemical risks (r = .68) and were less concerned about the requirement of reducing chemical risks (r = .47). The attitudes toward chemical risks and attitudes toward reduction were also positively correlated (r = .55). Trust in animal studies did not exhibit significant correlation with any of the other scales.

The authors relied on multiple regression analyses to predict the scale scores from demographic characteristics of the public sample. Examining only variables that made a statistically significant contribution to the regression equation revealed that sores on the attitude toward chemicals could be predicted fairly well (R = .49) using education, gender, and scientific training as variables. Scientific training, more education, male gender, and better health were all predictive of more favorable attitudes. Dose-response sensitivity was also somewhat predictable when health status, education and age were used as variables. Well-educated and healthy older people were more likely to be sensitive to the importance of dose. Demographic variables were not useful in predicting trust in animal testing.

Further regression analyses were performed to determine whether the differences between the public and toxicologists were merely demographic. The authors looked at questions on which the two groups disagreed using gender, race, education, and group status (member of the public versus member of the toxicologists) as predictors. They report that group status was far and away the most important predictor. Education, race, and gender accounted for significant but small amounts of the variance in responses to the questions.

In general, the results from Kraus, et al. (1992) paint a picture of confusion for both the public and toxicologists. It seems that the public is very insensitive to dose and highly concerned about the smallest exposure to toxic or carcinogenic chemicals. Indeed, it appears that intuitive toxicologists adopt a pattern of believing that contamination has a quality of being all or none. Concurrently, there is a spacious divergence of opinion among experts about many of the fundamental issues of risk assessment. In particular, they disagreed about the validity of animal and bacterial studies that are the foundation of their own science. It very well may be that the "gap" between the public and the experts may have as much to do with weaknesses in the science of risk assessment as they do with public misconception.

Mental Models and van Ravenswaay's Concept of Risk Perception

These particular examples of the mental methodology appear to address some of the major concerns of van Ravenswaay's three component concept. Steps are taken during the mental methodology process to elicit the beliefs that respondents bring to the table when they engage in risk judgements. By and large, it is the area of mental models that comes closest to accommodating van Ravenswaay's three components in a comprehensive manner. While there is no conscious effort made to mold the information into a broader assessment of the specific situations people are concerned about when answering the questionnaire, the need to determine what people are thinking and why they are concerned about that particular situation does assume a position of importance.

Perhaps the greatest difference between the two ideas is simply the depth of evaluation necessary to achieve the objective of eliciting information concerning risk perception. Even here, the differences are not staggering. While many chance and harm variables are left untouched by these particular studies it would not be impossible to include them relatively easily. It appears that the most significant difference is that mental model methods have not been specific enough to ensure that either respondents are evaluating the same scenarios or to determine the exact scenario of each respondent. Again, it is conceivable that the two concepts are asking the same question but probing to different depths.

Chapter 7: Conclusion

General comments

As stated at the beginning of the paper, there are few subjects that are more important to more people at the present time than controversies over harm to the environment and public health and safety from a variety of natural and human-made sources. Recent shifts in the political climate intensify the need for a more complete understanding of the risks associated with certain activities. Recent legislative efforts to increase the reliance of government agencies on risk analyses and benefit-cost analyses as decision tools are increasing the pressure on experts to provide a better understanding of the risks and benefits associated with human activities. Unfortunately, as risk assessment experts address these needs it is readily apparent that there is a disparity between their assessments or perceptions and those of the public. In the short-run this disparity can be a source of turmoil for many public policy officials. In the long-run they may find that blind allegiance to such analyses may bring political downfall.

In examining the literature on psychological research on risk perception we find that research has changed over time as new interests and needs were discovered. An initial interest in Starr's revealed preferences method and an interest in probability assessment and the decision making processes of individuals led to the development of the psychometric paradigm. Within the psychometric paradigm researchers began to gather crude estimates of people's perceptions of risk acceptability, perceptions of benefits and an inkling of understanding about the factors that influenced risk perception.

Supporters of the paradigm reached the conclusion that the concept "risk" means different things to different people. This is not so surprising as hazards affect people differently. Interestingly, it seems that people believe they are living in the midst of a risk-laden society. A great majority of the studies show that people are greatly concerned about nuclear energy, chemicals, and pesticides for a variety of reasons and in a variety of situations. This result remains puzzling when one considers the large amounts of capital and effort expended by industrialized nations in efforts to address many of the hazards that people face in their everyday lives. Also puzzling is the position taken by some political officials that the majority of the American public wants to see less regulation of technologies, businesses, environmental hazards, etc. Apparently, someone's wires are crossed preventing information from getting through to policy makers, researchers are receiving incorrect information, or there are other factors at work in the making of health and safety policy. The answer to this dilemma remains to be seen.

Early psychometric studies relied on factor analysis to examine the correlation between qualitative characteristics of risk across a wide and diverse range of hazards. Essentially, respondents were asked to rate the riskiness of a hazard and then to rate the hazards with respect to a varying set of characteristics. The respondents were on occasion asked directly about the acceptability of certain risks. In general however, little distinction is made between risk acceptability and risk perception. They garnered some interesting results that show that people often include more than just the number of deaths in to their judgement. However, from the van Ravenswaay perspective, there is reason to believe that they are only capturing a few of the factors that make up risk perception.

None of the psychometric studies examined for this paper attempted to account for the specific situations that respondents were thinking about as they answered the questionnaires. Because factors of chance, harm, and context are not controlled, comparison and interpretation are difficult if not impossible. Many of the studies made broad generalizations about how people were likely to respond to specific hazards based on average responses covering a diverse group of hazards. It took time and criticism to move researchers to begin studying specific hazards or groups of related hazards.

Studies of specific hazards have provided interesting results. For example, Sparks and Sheperd (1994) found that some potential food hazards may attract overoptimistic bias. The Kraus and Slovic study of railroad collisions points out that trying to represent diverse hazards with a homogenous category can lead to misleading inferences about the hazards. However, when compared to van Ravenswaay's concepts, even these types of studies fall short of controlling the various scenarios that respondents are judging.

The most recent developments in the field have come in the area mental modeling. This methodology grew out of an interest in how people come to understand the physical, biological, and chemical processes that dictate a hazard's creation and control. Mental models are defined as a set of principles from which people obtain predictions about a hazard's behavior. Through the use of influence diagrams researchers attempt to determine what people know and need to know about specific hazards. This represents a movement toward alignment with van Ravenswaay's concepts.

The task of allowing respondents to provide their own ideas of what is important in making a judgement about risk could easily be manipulated to account for as many of the elements of van Ravenswaay's concepts as possible. By utilizing both open-ended and closed-ended questions mental model researchers are gathering information about many of these elements already. Closed-ended or directed questions could be used to better ascertain the specific scenarios that respondents are judging.

Interest in the effects of trust and outrage on risk perception has also gathered strength recently. The results of studies examined in this review provide evidence that outrage has a statistically significant, but small influence on risk perception. In this reviewer's opinion, while it seems logical that outrage and trust should play some role in determining a person's perception of the risk of a hazard, more evidence is necessary before making the judgement that outrage and trust are important contextual variables.

Chance, Harm, and Context in the Literature

Elements of van Ravenswaay's three concepts are definitely found within the psychological research on risk perception. Most prominent are variables that can be categorized as elements of harm and context. Qualitative variables denoting chance were virtually nonexistent. Typically, elements of chance were addressed directly by providing the respondent with a definition of the population involved, the hazard(s) to be evaluated, and on occasion a specific timespan. Appendix 6-1 provides a rather lengthy portrayal of how common the elements are throughout the literature. A cursory glance at Appendix 6-1 is all that is needed to conclude that many of the dependent variables employed by psychological researchers are indeed elements of van Ravenswaay's concept of risk perception.

Only rarely were all three chance variables in the list tested for significance. Testing the significance of a specific timespan is virtually unheard of among the studies examined for this review. In terms of harm variables, the reader will find only the more important or common variables listed in Appendix 6-1. Of the listed variables, type of harm is only rarely a dependent variable and hardly ever completely specified. The most common were severity, dread, and catastrophic. The most common context variables are control, voluntary, and known risk. The least common context variable is existing risk management strategies. The most common variables are also most often found to be significant.

Implications for Economic Theory

What are the implications of the results garnered by psychological researchers for economic theory? Economists seek to develop estimates of the value of reducing the health risk associated with a wide range of hazards. The most common methods used by economists to estimate the benefits of risk reduction are hedonic, contingent valuation or averting expenditure methods. Each of these methods requires some measurement of the risk reduction people are valuing implicitly or explicitly. Studies employing hedonic or averting expenditure methods typically assume that respondents perceive risks in the same manner as scientists and experts do. Contingent valuation methodology typically proceeds on the assumption that the respondents perceive risks to be the same as the information provided to them within the survey instrument. These assumptions beg the question of whether economists' risk perception proxies are accurate. In all likelihood they are not accurate, as individuals are likely to differ in their evaluation of different risks.

If people are relying on heuristic reasoning to solve complicated problems there is every reason to believe that the estimates being gathered by economists are rife with error. The availability bias may be sufficiently large to cause severe problems with laypeoples' estimates of the risk associated with a hazard. This in turn can cause error to creep into economists' estimates of risk reduction.

Remember that economists' benefit estimation methods are based on some key assumptions. Hedonic and averting expenditures methods assume that respondents and scientists and experts perceive risks in the same manner. This hardly seems correct in the face of overwhelming evidence to the contrary. It is the disparity between their perceptions that has risk managers and policy makers in a tizzy. Contingent valuation methods attempt to avoid some problems by assuming that respondents perceive risks to be the same as the information they are given in a survey instrument. Would that it were so. What if people are biased against certain types of information as Tversky and Kahneman suggest or operate under the constraints of bounded rationality? If respondents are biased against processing certain types of information the way situations are presented to them quickly gains in importance. It may be that if the information is contrary to their beliefs that it will be disregarded as false or unreliable. Likewise, if people are very open to suggestion they may be easily swayed by the way a question is formulated.

Perhaps the greatest quandary stems from an assumption that lies just below the surface of the study of risk perception. There seems to be an implicit understanding that there is some "true" measure of risk. It is not necessary that this be so. Truth can be defined in a variety of ways and is as dependent on context as is risk perception itself. The definition of true risk has often been taken to mean an expert's assessment of the risk. There is no shortage of reasons to doubt the validity of such a definition. There is quite enough ambiguity in the conventions employed by experts to cause one to take pause before conceding the field to their assessments. In short, there may be no true measure of risk out "there." This makes the need for a broad-based definition of risk perception all the more important.

Finally, this review points out the need for further intense research of the processes involved in risk perception judgments. A multidisciplinary approach is required as risk perception is multidimensional. Measuring risk perception differs across disciplines and there is no general consensus on the "proper" way to perform measurements. Likewise, the characteristics of risk perception differ across disciplines. For example, van Ravenswaay (1994) points out that while psychologists are concerned with determining how people rank risky activities, risk assessment experts are interested in estimating the magnitude of risk related to a specific hazard. Developing a common definition of risk perception across disciplines would go far towards alleviating much of the difficulty in comparing studies. Perhaps van Ravenswaay's broad-based concept is one possibility.

The concepts of chance, harm, and context seem to be broad enough and powerful enough to encompass most, if not all, of the scenarios that respondents may be concerned about. There is also a good deal of flexibility within the concept. It should be relatively uncomplicated to mold the three components into much of the research that has already been completed by psychological researchers on risk perception. One major advantage to economists who might elect to employ such a concept is that it addresses one of the basic requirements of any economic analysis: defining the good in question. Working to elicit responses for all of the elements of the concept goes far toward making certain that everyone involved is on the same page in the book, so to speak. It may help reduce some of the error in the variables in our models of risk perception. And any economist or econometrician worth their salt knows that is a worthwhile effort.

Appendices

Appendix 2-1: Risk Perception, Benefit Perception, and Risk Acceptability

Study	Risk perception	Benefit perception	Risk acceptability
Alhakami and Slovic 1994	Yes	Yes	Yes
Bagjier and Moskowitz 1982	Yes	Yes	No
Barke and Jenkins-Smith 1993	Yes	No	Yes
Bord and O'Connor 1992	Yes	No	No
Bostrom, Fischhoff, and Morgan 1992 (Mental Models)	Yes	No	No
Burns, Slovic, Kasperson, Kasperson, Renn, and Emani 1993	Yes	Yes	No
Buss and Craik 1983	Yes	Yes	Yes
De Marchi 1991(Mental Model)	Yes	No	No
Englander, Farago, Slovic, and Fischhoff 1986	Yes	No	Yes
Fischer, Morgan, Fischhoff, Nair, and Lave 1991	Yes	Yes	Yes
Fischhoff, Slovic, Lichtenstein, Read, and Combs 1978	Yes	Yes	Yes
Fischhoff, Watson, and Hope 1984	No	Yes	Yes
Flynn, Burns, Mertz, and Slovic 1992	Yes	Yes	Yes
Flynn, Slovic, and Mertz 1994	Yes	No	Yes
Flynn, Slovic, and Mertz 1993	Yes	No	No
Gardner, Tiemann, Gould, DeLuca, Doob, and Stolwijk 1982	Yes	Yes	Yes
Gregory and Lichtenstein 1994	Yes	Yes	Yes
Gregory and Mendelsohn 1993	Yes	Yes	No

Appendix 2-1 (cont'd)

Harding and Eiser 1984	Yes	Yes	Yes
Hinman, Rosa, Kleinhesselink, and Lowinger 1993	Yes	No	No
Jenkins-Smith and Bassett 1994	Yes	No	No
Johnson and Luken 1987	Yes	No	No
Johnson and Tversky 1984	Yes	No	No
Karpowicz-Lazreg and Mullet 1993	Yes	No	No
Kivimäki and Kalimo 1993	Yes	No	No
Koné and Mullet 1994	Yes	No	No
Kraus and Slovic 1988	Yes	Yes	No
Kraus, Malmfors, and Slovic 1992	Yes	Yes	Yes
Kuyper and Vlek 1984	Yes	Yes	Yes
MacGregor and Slovic 1986	Yes	Yes	Yes
MacGregor, Slovic, Mason, Detweiler, Binney, and Dodd 1994	Yes	Yes	Yes
Maharik and Fischhoff 1992	Yes	No	Yes
Maharik and Fischhoff 1993	Yes	No	No
McDaniels, Kamlet, and Fischer 1992	Yes	Yes	Yes
Morgan, Slovic, Nair, Geisler, MacGregor, Fischhoff, Lincoln, and Florig 1985	Yes	Yes	Yes
Renn, Burns, Kasperson, Kasperson, and Slovic 1992	Yes	Yes	Yes
Sandman, Weinstein, and Miller 1994	Yes	No	No
Sandman, Miller, Johnson, and Weinstein 1993	Yes	Yes	Yes
Savage 1993	Yes	No	No

Appendix 2-1 (cont'd)

Slovic, Fischhoff, and Lichtenstein 1979	Yes	No	No
Slovic, Fischhoff, and Lichtenstein 1982	Yes	Yes	Yes
Slovic, Fischhoff, and Lichtenstein 1985	Yes	Yes	Yes
Sparks and Sheperd 1994	Yes	Yes	No
Tiegen, Brun, and Slovic 1988	Yes	No	No
von Winterfeldt, John, and Borcherding 1981	Yes	No	No
Weinstein and Sandman 1992	Yes	Yes	No
Viscusi and Cavallo 1994	Yes	No	No
Vlek and Stallen 1981	Yes	Yes	Yes
N = 48 total studies. At right is the percentage of studies addressing the part. item.	0.98 (times 100)	0.54 (times 100)	0.5 (times 100)

Appendix 3-1: Risk Perception Measurement Methods

Study	Variables/Questions	Scale
Alhakami and Slovic 1994	Risk	1 = not at all risky, 7 = very risky.
Barke and Jenkins-Smith 1993	Risk	1 = not at all risky, 5 = very risky.
Bord and O'Connor 1992	1. Concern 2. Respondents est. number of new cases/100 people of nine illnesses due to toxic chemical at waste sites.	1 = Extreme risk, 4 = not at all.
Burns, Slovic, Kasperson, Kasperson, Renn, and Emani 1993	1. Future risk 2. Perceived Managerial Incompetence	1 = not at risk, 9 = at very great risk. 1 = being managed properly, 9 = not being managed properly.
Buss and Craik 1983	Perceived Risk	Ranked 30 items 1-30 based on 1= lowest 30 =highest. Then respondents provided ratings of perceived risk; 1 = least risky and used magnitude values to rank others accordingly. (1.2 is 20% higher than one.)
De Marchi 1991(Mental Model)	Mental associations triggered by "risk."	1. What does the word risk make you think of? 2. So for you risk is...?
Englander, Farago, Slovic, and Fischhoff 1986	Perceived risk (relative ranking)	10 = least risky, remainder of scale open-ended.
Fischer, Morgan, Fischhoff, Nair, and Lave 1991	Willingness to pay (WTP) for eliminating any personal risk over lifetime.	1 = not much, 5 = great deal.
Fischhoff, Slovic, Lichtenstein, Read, and Combs 1978	Perceived risk (relative ranking)	10 = least risky , remainder of scale open-ended.

Appendix 3-1 (cont'd)

Flynn, Burns, Mertz, and Slovic 1992	1. Risk index: composed of the summation of responses to six questions. 2. Perceived risk (Image score)	1 = low risk, 5 = high potential risk. Word association scored by respondents on 5 point scale from -2 to +2.
Flynn, Slovic, and Mertz 1994	Health risk	1 = almost no health risk, 4 = high health risk
Gardner, Tiemann, Gould, DeLuca, Doob, and Stolwijk 1982	Perceived Risk	Uses horizontal line with no risk at one end and very great risk at the other. Respondents place X on line according to risk.
Gregory and Mendelsohn 1993	Perceived risk	1=low risk, 7=high risk.
Harding and Eiser 1984	1. Risk 2. Likely	Bipolar continuous rating scales with no risk, great risk, likely, not likely as endpoints.
Hinman, Rosa, Kleinhesselink, and Lowinger 1993	Dread, knowledge of risk, voluntariness, controllability, and newness of risk.	7-point scale where 1 = low and 7 = high.
Jenkins-Smith and Bassett 1994	1. Production of nuclear energy 2. Temp. storage of waste at prod. site 3. Transportation of waste 4. Permanent storage of waste	Same scale for all variables; 1 = extreme risk, 5 = no risk.
Johnson and Luken 1987	Seriousness	0 = not serious, 10 = very serious
Johnson and Tversky 1984	No specific variable	18 hazards most frequently mentioned and est. to have highest fatalities by respondents ranked 1-18.
Karpowicz-Lazreg and Mullet 1993	Risk level	0-100 point scale with 10 point intervals. Respondent marks level with an X.
Kivimäki and Kalimo 1993	1. Nuclear plant safety 2. Likelihood of a serious accident 3. Personal risk at work 4. Risk to others at work 5. Risk of destroying machine or output or notable damage at work	1 = safe, 5 = hard to say 1 = certain, 5 = certainly not 1 = never, 5 = always 1 = never, 5 = always 1 = never, 5 = always

Appendix 3-1 (cont'd)

Koné and Mullet 1994	Risk	Same scale as Karpowicz-Lazreg and Mullet 1993.
Kraus and Slovic 1988	Study 1 no specific variable Study 2 overall level of risk	10 = low , similar to Fischhoff, et al. 1978. 1 = not risky, 7 = extreme risk
Kuyper and Vlek 1984	Overall riskiness	1 = not risky, 5 = extreme risk
Maharik and Fischhoff 1992	1. Favor the use of the technology. 2. The technology can be made sufficiently safe. 3. The technology is adequately safe at present.	1 = completely favor, 7 = completely oppose 1 = definitely can, 7 = definitely cannot 1 = definitely is, 7 = definitely is not.
McDaniels, Kamlet, and Fischer 1992	Voluntariness, severity, knowledge of risk, controllability, dread, personal exposure, public exposure, and overall risk	7-point scales where 1 = low and 7 = high.
MacGregor, Slovic, Mason, Detweiler, Binney, and Dodd 1994	Respondents were asked the following: 1. Accidents involving transport of hazardous materials are inevitable. 2. From what I know, current methods of transport through my community are safe. 3. Can nuclear waste be transported in an acceptably safe manner? 4. Transport of nuclear waste over highways represents a small relative risk. 5. Would you change your travel route to avoid transport route? 6. Given choice of transport or storing waste, is risk of transport greater than storage? 7. Will transport of nuclear waste be harmful or beneficial to you personally? 8. Level of concern for public health effects of transport.	1 = strongly agree, 4 = strongly disagree Same as above Yes or no 1 = strongly agree, 4 = strongly disagree Yes or no 1 = much greater, 4 = much less 1 = entirely harmful, 4 = entirely beneficial, and 5 = balance out 1 = very concerned, 4 = not concerned at all.
Morgan, Slovic, Nair, Geisler, MacGregor, Fischhoff, Lincoln, and Florig 1985	Ranked assorted hazards	10 = low, similar to Fischhoff, et al. 1978.

Appendix 3-1 (cont'd)

Renn, Burns, Kasperson, Kasperson, and Slovic 1992	1. Future risk 2. Dread 3. Managerial incompetence 4. Blame	1-7 or 0-8 point scale 1-7 or 0-8 point scale 0-8 point scale 0-8 point scale.
Sandman, Miller, Johnson, and Weinstein 1993	Seriousness	1 = no risk, 6 = very serious risk
Sandman, Weinstein, and Miller 1994	1. Perceived likelihood of illness 2. Perceived danger 3. Expected concern 4. Expected fear Added together to create perceived threat.	1 = no chance, 7 = certain 1 = no danger, 6 = extreme 1 = no concern, 5 = extreme 1 = no fear, 5 = extreme fear range of 4-23.
Savage 1993	1. Dread 2. Unknown 3. Personal exposure	1 = calm, 7 = nervous 1 = don't know about risk, 7 = well-informed about risk 1 = no personal threat, 7 = high personal threat.
Slovic, Fischhoff and Lichtenstein 1979, 1981, 1982, and 1985	No specific variable	10 = low similar to Fischhoff, et al. 1978. 1985 uses geometric mean rather than arithmetic mean.
Sparks and Sheperd 1994	Examined perceptions of 23 "characteristics" of risk including: seriousness, concern, seriousness for future generations, threat of disastrous consequences, dread, becoming more serious, size of risk, personal risk, accuracy of own assessment, fatality likelihood, number of exposed, number of affected, and even distribution of risks.	7-point scales where 1 = low and 7 = high.
Tiegen, Brun, and Slovic 1988	Risk level	Scale of 0-100 (0 = not risky and 100 = extreme risk.)
Viscusi and Cavallo 1994	1. Danger 2. Concern 3. Danger-Test (test lighter) 4. Concern-Test (test lighter)	All four variables use a 10-point scale with 1 = not dangerous and 10 = extremely dangerous.
Vlek and Stallen 1981	Respondents ranked 26 hazards according to relative risk, 1-26.	

Appendix 3-1 (cont'd)

von Winterfeldt, John, and Borcherding 1981	1. Overall risk 2. Respondents also provided three estimates : annual individual fatality probability average number of fatalities per year number of fatalities in a disaster	0-100 with 0 = little risk and 100 = extreme

Appendix 6-1: Variables of Chance, Harm, and Context and Their Significance

	Studies							
	Bostrom, et al.		Sparks & Sheperd		Alhakami & Slovic		Viscusi & Cavallo	
Variable (See Table 3-2 for list of qual. var. incld. here)	Incld. item	Sig.	Incld item	Sig.	Incld. item	Sig.	Incld. item	Sig.
CHANCE								
Particular Population	Yes	No test	Yes	Yes	Yes	No test	Yes	No test
Hazard	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Specific time period	No		No		No		Yes	No test
HARM								
Type of harm	No		No		No		No	
Severity	Yes	Yes	Yes	Yes	Yes	No test	No	
Dread	No		Yes	Yes	Yes	Yes	No	
Mitigation cost	No		Yes	Yes	No		No	
Painfulness	No		No		Yes	No test	No	
Catastrophic	No		Yes	Yes	Yes	Yes	No	
Immediacy	Yes	No	No		No		No	
Consequences fatal	No		Yes	Yes	Yes	Yes	No	
CONTEXT								
Risk mgmt strategies in place	Yes	No test	No		No		Yes	Yes
Control	No		Yes	Yes	Yes	No	No	
Chance of hazards occurring given strategies	No		No		No		No	
Voluntary	No		Yes	Yes	Yes	No	No	
Amount of exposure	No		Yes	Yes	No		No	
Risk is unknown	No		Yes	Yes	Yes	No	No	
Susceptibility of harm given level of exposure	No		No		No		No	
Some level of uncertainty about context variables	No		No		No		No	

Appendix 6-1 (cont'd)

Studies

Variable	Gregory & Lich.		J-Smith & Bassett		Weinstein /Sandman.		Flynn, Slovic & Mertz	
	Incld. item	Sig.	Incld. item	Sig.	Incld. item	Sig.	Incld. item	Sig.
CHANCE								
Particular Population	No		No		Yes	Yes	Yes	Yes
Hazard	Yes	No test	Yes	No test	Yes	No test	Yes	No test
Specific time period	No		No		No		No	
HARM								
Type of harm	Yes	No test	No		No		Yes	Yes
Severity	No		No		Yes	Yes	No	
Dread	No		No		No		No	
Mitigation cost	No		No		Yes	No	No	
Painfulness	No		No		No		No	
Catastrophic	No		No		No		No	
Immediacy	No		No		No		No	
Consequences fatal	No		No		Yes	Yes	No	
CONTEXT								
Risk mgmt strategies in place	No		No		Yes	Yes	No	
Control	No		No		No		No	
Chance of hazards occurring given strategies	No		No		No		No	
Voluntary	No		No		No		No	
Amount of exposure	No		No		Yes	Yes	No	
Risk is unknown	No		No		No		No	
Susceptibility of harm given level of exposure	No		No		Yes	Yes	No	
Some level of uncertainty about context variables	No		No		No		No	

Appendix 6-1 (cont'd)

	Studies							
	Morgan et al. 1985		Fischer et al. 1991		McDaniels et al.		Bord &O'Connor	
Variable	Incld. item	Sig.	Incld. item	Sig.	Incld. item	Sig.	Incld. item	Sig.
CHANCE								
Particular Population	No		No		Yes	No test	Yes	No test
Hazard	Yes	No test	Yes	No test	Yes	Yes	Yes	Yes
Specific time period	No		No		Yes	No test	No	
HARM								
Type of harm	No		Yes	Yes	Yes	Yes	Yes	Yes
Severity	Yes	No	Yes	Yes	Yes	Yes	Yes	Yes
Dread	Yes	Yes	No		Yes	Yes	No	
Mitigation cost	No		Yes	Yes	No		No	
Painfulness	No		No		No		No	
Catastrophic	No		No		No		No	
Immediacy	Yes	Yes	No		No		No	
Consequences fatal	No		No		No		No	
CONTEXT								
Risk mgmt strategies in place	Yes	Yes	Yes	Yes	No		Yes	Yes
Control	Yes	No	No		Yes	Yes		
Chance of hazards occurring given strategies	No		No		No		No	
Voluntary	No		No		Yes	No		
Amount of exposure	Yes	Yes	No		Yes	Yes	No	
Risk is unknown	Yes	Yes	No		Yes	Yes		
Susceptibility of harm given level of exposure	No		No		Yes	No test	No	
Some level of uncertainty about context variables	No		No		No		Yes	No

Appendix 6-1 (cont'd)

	Studies							
	MacGregor et al.		Kone & Mullet		Sandman et al. 1994		Gregory & Mendelsohn	
Variable	Incld. item	Sig.	Incld. items	Sig.	Incld. items	Sig.	Incld. items	Sig.
CHANCE								
Particular Population	Yes	Yes	Yes	No test	Yes	No test	Yes	No test
Hazard	Yes	Yes	No		Yes	Yes	Yes	Yes
Specific time period	Yes	No	No		Yes	No test	Yes	No test
HARM								
Type of harm	Yes	Yes	Yes	Yes	Yes	Yes	No	
Severity	No		No		No		Yes	Yes
Dread	No		No		No		Yes	Yes
Mitigation cost	No		No		No		Yes	Yes
Painfulness	No		No		No		No	
Catastrophic	No		No		No		No	
Immediacy	No		No		No		Yes	Yes
Consequences fatal	No		No		No		Yes	No
CONTEXT								
Risk mgmt strategies in place	Yes	No	No		No		No	
Control	No		No		No		No	
Chance of hazards occurring given strategies	Yes	Yes	No		No		No	
Voluntary	No		No		No		Yes	No
Amount of exposure	No		No		Yes	Yes	No	
Risk is unknown	No		No		No		No	
Susceptibility of harm given level of exposure	No		No		Yes	Yes	No	
Some level of uncertainty about context variables	No		No		No		No	

Appendix 6-1 (cont'd)

	Studies							
	Savage		Kivimaki and Kalimo		Barke & J-Smith		Hinman et al.	
Variable	Incld. item	Sig.	Incld. item	Sig.	Incld. item	Sig.	Incld. item	Sig.
CHANCE								
Particular								
Population	No		Yes	Yes	Yes	No test	No	
Hazard	Yes	Yes	Yes	Yes	Yes	Yes	No	
Specific								
time period	No		Yes	Yes	No		No	
HARM								
Type of harm	Yes	Yes	No		Yes	Yes	Yes	Yes
Severity	Yes	Yes	No		Yes	Yes	No	
Dread	Yes	Yes	No		No		Yes	Yes
Mitigation cost	No		No		No		No	
Painfulness.	No		No		No		No	
Catastrophic	No		No		No		No	
Immediacy	No		No		No		Yes	No
Consequences fatal	No		No		No		No	
CONTEXT								
Risk mgmt strategies								
in place	Yes	No test	Yes	Yes	Yes	Yes	No	
Control	No		No		No		Yes	Yes
Chance of hazards								
occurring given strategies	No		No		Yes	Yes	No	
Voluntary	No		No		No		Yes	No
Amount of exposure	No		No		No		No	
Risk is unknown	No		No		No		Yes	No
Susceptibility of harm								
given level of exposure	Yes	No test	No		No		No	
Some level of uncertainty								
about context variables	No		No		No		No	

Appendix 6-1 (cont'd)

	Studies							
	Sandman et al. 1993		Englander et al. 1986		Fischhoff et al 1978		Gardner et al. 1982	
Variable	Incld. items	Sig.	Incld. items	Sig.	Incld. items	Sig.	Incld. items	Sig.
CHANCE								
Particular								
Population	Yes	No test	Yes	No test	No		Yes	No test
Hazard	Yes	Yes	No		No		No	
Specific								
time period	Yes	No test	No		No		No	
HARM								
Type of harm	Yes	No	Yes	Yes	Yes	Yes	No	
Severity	Yes	No	Yes	Yes	No		No	
Dread	No		Yes	Yes	Yes	Yes	Yes	Yes
Mitigation cost	Yes	No	No		No		No	
Painfulness	No		No		No		No	
Catastrophic	No		Yes	No	Yes	No	Yes	Yes
Immediacy	Yes	No	Yes	No	Yes	Yes	No	
Consequences fatal	No		Yes	No test	Yes	Yes	No	
CONTEXT								
Risk mgmt strategies								
in place	Yes	Yes	No		No		No	
Control	No		Yes	No	Yes	No	No	
Chance of hazards								
occurring given strategies	Yes	Yes	No		No		No	
Voluntary	No		Yes	No	Yes	No	No	
Amount of exposure	Yes	No	No		No		No	
Risk is unknown	No		Yes	Yes	Yes	Yes	Yes	Yes
Susceptibility of harm								
given level of exposure	No		No		No		No	
Some level of uncertainty								
about context variables	No		No		No		No	

Appendix 6-1 (cont'd)

	Studies							
	Harding &Eiser		Kraus &Slovic		Kuyper & Vlek		Tiegen et al. 1988	
Variable	Incld. items	Sig.	Incld. items	Sig.	Incld. items	Sig.	Incld. items	Sig.
CHANCE								
Particular								
Population	No		No		No		Yes	No test
Hazard	No		Yes	Yes	Yes	Yes	Yes	Yes
Specific								
time period	No		No		No		No	
HARM								
Type of harm	No		No		No		No	
Severity	No		No		No		No	
Dread	Yes	Yes	Yes	Yes	No		Yes	Yes
Mitigation cost	No		No		No		No	
Painfulness	No		No		No		No	
Catastrophic	No		Yes	Yes	Yes	Yes	Yes	Yes
Immediacy	Yes	No	No		No		Yes	No
Consequences fatal	Yes	Yes	No		No		Yes	Yes
CONTEXT								
Risk mgmt strategies								
in place	No		No		No		No	
Control	No		Yes	Yes	No		Yes	No
Chance of hazards								
occurring given strategies	No		No		No		No	
Voluntary	Yes	No	Yes	Yes	Yes	Yes	Yes	No
Amount of exposure	No		No		No		No	
Risk is unknown	Yes	No	Yes	Yes	No		Yes	No
Susceptibility of harm								
given level of exposure	No		No		No		No	
Some level of uncertainty								
about context variables	No		No		No		No	

Appendix 6-1 (cont'd)

	Studies						
	Buss & Craik		Johnson & Tversky		Slovic, Fisch., Licht.		N = 31 studies
Variable	Incld. item	Sig.	Incld item	Sig.	Incld. item	Sig.	% of studies incl. item
CHANCE							
Particular Population	Yes	Yes	Yes	Yes	Yes	Yes	68%
Hazard	Yes	Yes	Yes	Yes	Yes	Yes	81%
Specific time period	No		Yes	No test	No		22%
HARM							
Type of harm	No		No		No		45%
Severity	Yes	Yes	No		Yes	Yes	48%
Dread	Yes	Yes	Yes	Yes	Yes	Yes	52%
Mitigation cost	No		No		No		16%
Painfulness	No		No		No		3%
Catastrophic	Yes	No	Yes	Yes	Yes	Yes	35%
Immediacy	Yes	No	Yes	Yes	Yes	No	39%
Consequences fatal	Yes	Yes	Yes	Yes	Yes	Yes	35%
CONTEXT							
Risk mgmt strategies in place	No		No		No		35%
Control	No		Yes	Yes	Yes	Yes	35%
Chance of hazards occurring given strategies	No		No		No		10%
Voluntary	Yes	No	Yes	Yes	Yes	No	45%
Amount of exposure	No		No		No		19%
Risk is unknown	Yes	Yes	Yes	Yes	Yes	No	45%
Susceptibility of harm given level of exposure	No		No		No		13%
Some level of uncertainty about context variables	No		No		No		3%

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