

Intuitive Toxicology  
Neil et al.

revised

8/93

Paul Slovic  
Decision Research  
1201 Oak Street  
Eugene, Oregon 97401  
(503) 485-2400

## **Intuitive Toxicology: Expert and Lay Judgments of Chemical Risks**

Nancy Neil,<sup>1</sup> Torbjörn Malmfors,<sup>2</sup> and Paul Slovic<sup>3</sup>

*<sup>1</sup>29717 Beach Drive N.E., Poulsbo, Washington*

*<sup>2</sup>Malmfors Consulting AB, Vastmannagatan 48, S-113 25 Stockholm*

*<sup>3</sup>Decision Research, 1201 Oak Street, Eugene, Oregon*

**Key Words**

risk perception, risk communication, risk management, risk analysis, risk assessment

### Abstract

Human beings have always been intuitive toxicologists, relying on their senses of sight, taste, and smell to detect harmful or unsafe food, water, and air. As we have come to recognize that our senses are not adequate to assess the dangers inherent in exposure to a chemical substance, we have created the sciences of toxicology and risk assessment to perform this function. Yet despite this great effort to overcome the limitations of intuitive toxicology, it has become evident that even our best scientific methods still depend heavily on extrapolations and judgments in order to infer human health risks from animal data. Many observers have acknowledged the inherent subjectivity in the assessment of chemical risks and have indicated a need to examine the subjective or intuitive elements of expert and lay risk judgments. Such an examination was begun by surveying members of the Society of Toxicology and the lay public about basic toxicological concepts, assumptions, and interpretations. The results demonstrated large differences between toxicologists and laypeople, as well as differences between toxicologists working in industry, academia, and government. In addition, toxicologists were found to be sharply divided in their opinions about the ability to predict a chemical's effect on human health on the basis of animal studies. These results place the problems of risk communication in a new light. Although the survey identifies misconceptions that experts should clarify for the public, it also suggests that controversies over chemical risks may be fueled as much by limitations of the science of risk assessment and disagreements among experts as by public misconceptions.

## Introduction

Human beings have always been intuitive toxicologists, relying on their senses of sight, taste, and smell to detect unsafe food, water, and air. As we have come to recognize that our senses are not adequate to assess the dangers inherent in exposure to a chemical substance, we have created the sciences of toxicology and risk assessment to perform this function. Massive regulatory establishments have been formed to oversee the use of these sciences for standard setting and policy making. Yet despite this enormous effort to overcome the limitations of intuitive toxicology, it is becoming increasingly clear that even our best scientific methods still depend heavily on judgments in order to infer human health risks from laboratory data on animals. Many observers have acknowledged the inherent subjectivity in the assessment of chemical risks and have indicated a need to examine the intuitive elements of expert and lay risk judgments. In this project, we began such an examination by surveying members of the Society of Toxicology and the lay public about basic toxicological concepts, assumptions, and interpretations.

One does not need a survey to see that the American public is greatly concerned with the production, use, transport, and disposal of many chemical products and that scientific assessments of chemical risks are generally unpersuasive when used to resolve conflicts regarding these activities. The present research is motivated by the premise that different assumptions, conceptions, and values underlie much of the discrepancy between expert and lay views of chemical risks. We attempted to address this issue by exploring the cognitive models, assumptions, and inference methods that comprise laypeople's "intuitive

toxicological theories" and comparing these theories with the cognitive models, assumptions, and inference methods of scientists working in the field of toxicology.

### Methods

We began by identifying several fundamental principles and judgmental components within the science of risk assessment. Questions were developed based on these fundamentals in order to determine the extent to which laypeople and experts share the same beliefs and conceptual framework. Our questions addressed the following topics:

- 1) dose-response sensitivity
- 2) trust in animal and bacterial studies
- 3) attitudes towards chemicals
- 4) attitudes towards reducing chemical risks
- 5) conceptions of toxicity including the toxicity of natural vs. synthetic substances and the toxicity of prescription drugs vs. chemicals in general
- 6) interpretation of evidence regarding cause-effect relationships between exposure to chemicals and human health.

Questions on these topics were incorporated into a single questionnaire, designed for both experts and the public. Each question was designed, whenever possible, according to a guiding hypothesis about how experts and "lay toxicologists" might respond. For example, perhaps the most important principle in toxicology is the fact that "the dose makes the poison." Any substance can cause a toxic effect if the dose is great enough. Thus we

expected experts to be quite sensitive to considerations of exposure and dose when responding to questions on this topic. In contrast, the often observed concerns of the public regarding very small exposures or doses of chemicals led us to hypothesize that the public would have more of an "all or none" view of toxicity and would be rather insensitive to concentration, dose, and exposure (thus equating exposure with harm). We also expected laypersons to view natural substances as less toxic than synthetic substances, and experts to recognize the potential toxicity of natural substances as well as synthetic ones.

Because the science of toxicology and the discipline of risk assessment rely so heavily upon animal studies, we expected that experts would have a more favorable view than laypersons regarding the value of such studies. The prediction that laypersons lack sensitivity to dose-response considerations and thus fear even small exposures to toxic or carcinogenic substances led us to predict that they would exhibit far more negative general attitudes towards chemicals than experts. Similarly, we expected that laypersons' concerns about small exposures would cause them, more than experts, to want reduction and even elimination of chemical risks, regardless of cost.

We hypothesized that laypersons would perceive chemicals in prescription drugs as less toxic than chemical used in pesticides. Further, we expected that laypersons' direct experiences with medicines and their knowledge of the risk of overdose would make them more likely to recognize that the dose makes the poison for prescription drugs than for chemicals in general. Similarly, we expected that a 1 in 10,000,000 lifetime risk would be

less worrisome if it came from taking a prescription drug than if it came from exposure to a chemical.

One of our questions examined the interpretation of evidence pertaining to the cause of birth defects observed in a region where pesticides had been used. We hypothesized that experts would believe that the evidence presented was not sufficient to indict pesticides as the cause of the observed malformations, whereas laypersons would be more inclined to view the association between pesticides and birth defects as causal.

Extensive pretesting was necessary to develop questions that were not too technical for laypeople to answer yet were not too general or oversimplified for toxicologists to answer. Question development and pretesting took almost one year. The resulting questionnaire, was subsequently completed by 170 members of the Society of Toxicology and 262 members of the general public in Portland, Oregon. Subsequent studies administered various subsets of the questions to approximately 300 residents of Portland, 600 participants in a nationwide market research study, and more than 3000 members of the public nationwide, in order to verify the reliability of the findings from the initial Portland sample. The major findings are summarized below.

### Results

Our primary objective was to describe and compare responses of laypeople and toxicologists and to test a number of hypotheses about the differences between the public's views as "intuitive toxicologists" and the views of experts. In general, we believe that this aspect of the study was successful. Toxicologists and laypeople were found to differ greatly,

documenting some common assumptions (e.g., that the public believes natural chemicals to be safer than synthetic ones) and verifying many of the other hypotheses that motivated the questionnaire.

Of particular importance is the finding that the public is much less sensitive than the experts to considerations of dose and exposure. Although the public recognizes the importance of these factors in some domains (e.g., prescription drugs), they generally tend to view chemicals as either safe or dangerous and they appear to equate even small exposures to toxic or carcinogenic chemicals with almost certain harm. This orientation was found to be associated with high levels of concern regarding chemicals, including very small residues of chemicals on food, and a desire to reduce chemical risks at any cost. It was sobering to find that 40% of our public respondents said that they do everything they can to avoid contact with chemicals and chemical products in their daily lives. It is also remarkable to find that less than 50 percent of the public respondents in the Portland sample and less than 25 percent in the national sample recognized that exposure to a chemical that is carcinogenic does not make one likely to get cancer later in life.

Although we were not able to develop a precise description of the lay mental models of how a chemical carcinogen works, our results are consistent with a contagion or contamination model that is obviously very different from the kinds of models that toxicologists hold. We need to probe further to understand the mechanisms by which people believe chemicals induce various kinds of harm.

Several other findings were noteworthy: a) the public's tendency to attribute causality to a temporal association between pesticide use and birth defects; b) the strong negative attitudes of the public towards chemicals and their risks; c) the relatively favorable perceptions of prescription drugs, despite the fact that such drugs can be quite harmful; d) the finding that 30% of the public respondents did not agree that a 1 in 10,000,000 lifetime risk of cancer from exposure to a chemical was too small to worry about; and e) the finding that men and more highly educated persons were somewhat less concerned about chemical risks—in general, responses of college-educated persons were slightly more similar to responses of toxicologists than were responses of persons with less education.

One of the major surprises in the data was the *lack* of difference between the public and toxicologists with regard to their confidence in extrapolation from animal studies. Both groups were divided in their opinions and the high percentage of experts who lacked confidence in animal studies is particularly noteworthy in light of the extensive reliance on such studies in risk management. The public's trust in extrapolation from animal studies increased greatly when these studies were said to produce evidence of carcinogenicity.

Among the most important findings in this study was the great divergence of opinion among the toxicologists themselves about fundamental issues in risk assessment and, in particular, the high percentage of toxicologists who doubted the validity of the animal and bacterial studies that form the backbone of their science. These results provide a quantitative portrayal of the criticisms and disagreements that appear in the technical literature and occasionally in the news media. These results also clash with the optimistic messages given

the public about the ability of animal tests to evaluate the risks to humans from exposures to chemicals.

We also found an affiliation bias: toxicologists working for industry saw chemicals as more benign than did their counterparts in academia and government. The industrial toxicologists we surveyed were somewhat more confident than other experts in the general validity of animal tests for predicting human health effects. However, when a test was said to provide evidence for carcinogenicity the industrial experts tended to be less confident than others about its relevance for humans.

### Discussion

One of the major motivations behind this study was to develop an understanding of the differences between the ways that professional toxicologists and laypersons assess chemical risks, in order to facilitate communication and perhaps reduce the "gap" between expert and lay views. To a certain extent, some of the present results do point toward concepts that experts should clarify for the public. For example, it is obvious that the words "toxic" and "carcinogenic" mean very different things to experts and laypersons. If scientists could impart a better understanding of these concepts, and their relationship to exposure, then significant progress most certainly will have been achieved.

However, the present results also suggest that the controversies over chemical risks in our society may be fueled as much by weaknesses in the science of risk assessment as by misconceptions of the public. Our data (and those of other researchers as well) indicate that scientists do not agree whether their main method of testing is reliable or accurate in

predicting human health effects and that scientists who work for industry see fundamental issues quite differently from their colleagues in academia and government.

These results provide insight into the problems of risk communication. Our risk-management processes are open and adversarial—we battle in courtrooms and community halls, in view of the media, with experts on each side of the issue attacking the other's credibility, models, and data. The young science of risk assessment is too fragile, too indirect, to prevail in an adversarial atmosphere. Risk assessment, though invaluable to regulators in the design of management strategies, is not at all convincing to the public. Perhaps this should not surprise us, given the many criticisms of risk assessment in the literature. Our survey indicates that these criticisms are not a minority view. The affiliation bias we and others have observed is a natural outgrowth of the scientific ambiguity—but a disturbing one nonetheless. It feeds the public sense of distrust.

Our report concludes that risk assessment has been oversold because of the need to rationalize decisions about chemicals. The challenge to toxicologists and risk assessors is clear. These scientists must look anew at the strengths and limitations of their craft. They should work to develop stronger, more definitive ways to assess chemical risks. They should play a greater role in interpreting the health implications of their data for the public. In doing so, they should acknowledge the subjective elements, judgments, and assumptions inherent in their analyses, as well as the degree of uncertainty in their conclusions. Above all, they must protect the young science of risk assessment from being misrepresented, misused, and abused in the regulatory process.

### Acknowledgments

This paper is an abbreviated version of an article published in *Risk Analysis*, 1992,  
12, 215-232.