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Need to Know: Analytical and Psychological Criteria

Baruch Fischhoff*

The outcomes of many legal proceedings depend on whether some people were adequately informed regarding risks that they have taken. For example, medical malpractice suits may hinge on whether patients provided informed consent to procedures. Product liability suits may focus on the adequacy of consumer or operator warning labels. The managers of industrial facilities need to get out the word regarding potential and actual accidents. One response to this demand is routinely disseminating any information that could conceivably be relevant to someone. Unfortunately, that strategy ignores both the limits to recipients' overall information-processing capacity and their difficulty with comprehending particular kinds of information. A general approach is offered here for setting communication priorities and determining their adequacy.

INTRODUCTION

Individuals and organizations often bear a duty to inform others whose welfare their actions can affect. Physicians must ensure that their patients understand the risks of taking and declining medical procedures. Pharmaceutical firms must do much the same for potential consumers of their products. So must food processors, although they typically need to say much less, except to individuals in vulnerable populations (e.g., those with acute food allergies). Firms and government agencies managing hazardous facilities often must inform their neighbors (or nation) about the health, safety and environmental risks that they create. The penalties for adjudicated—or just perceived—failure to inform can be se-

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vere. They may include financial penalties, costly delays and public censure (even incarceration, in rare cases).

A conceptually simple response to this duty is making available any information that anyone could possibly want. Unfortunately, that strategy is anything but practically simple for anyone involved. Those who bear the duty could, conceivably, be held responsible for providing—and perhaps even creating—any imaginable kind of evidence. Those who need to be informed face the chore of sorting through any assemblage of facts that might be thrown at them. At the end of the day, this policy provides neither providers nor recipients the guidance and protection that they seek, while creating needless burdens.¹

Having ready access to all such information may be an important legal right, even if it is rarely exercised. Knowing that access is possible, firms may produce different risks. However, individuals facing specific choices are better served by a more practical communication strategy: tell them what they most need to know; stop when they know enough to make the decisions facing them. The remainder of this article focuses on three examples of how this strategy might be executed, drawing on the analytical and empirical tools of behavioral decision theory.² Conceptualization of the task involves the following steps: 1) Conduct a formal analysis of the decision problem, identifying those facts, knowledge of which would have the greatest impact on the expected utility of the decision for individuals who otherwise know nothing; 2) Determine what the decision-makers already know; 3) Create and evaluate communications providing the most important missing information; 4) Compare post-communication knowledge with the *acceptable level of misunderstanding*, given the legal and ethical constraints of the situation.

1. See generally Jon F. Merz, *On a Decision-Making Paradigm of Medical Informed Consent*, 14 J. Legal Med. 231 (1993) (speaking about the legal implications of informed consent in the medical and pharmaceutical fields); Jon F. Merz & Baruch Fischhoff, *Informed Consent Doesn't Mean Rational Consent: Cognitive Limitations on Decision-Making*, 11 J. Legal Med. 321 (1990) (explaining that the use of decision analysis tools is a more appropriate way to establish what constitutes adequate informed consent than using arbitrary legal definitions).

2. For general introductions to the field, see Scott Plous, *The Psychology of Judgment and Decision Making* (1993); J. Frank Yates, *Judgment and Decision Making* 1-13 (1990); Robyn M. Dawes, *Rational Choice in an Uncertain World* (Jerome Kagan ed., 1988); Detlof von Winterfeldt & Ward Edwards, *Decision and Behavioral Research* (1986).

Although these steps could be followed in a linear process, it may be appropriate to cycle back at any point. For example, if understanding is inadequate (step 4), then communications must be improved (step 3). If it is unclear how to communicate a critical detail (step 3), then further study of decision-maker beliefs is warranted (step 2). If studying those beliefs reveals a misspecification in the formal model, then it must be amended (e.g., in order to include a consequence that the modelers have neglected, but decision-makers describe as a matter of concern).

These steps are, of course, the basis of any conscientious communication act.³ Even in casual conversation, one attempts to identify things that others need to know and to say them so that they will be understood as intended, recognizing that new messages are interpreted in the context of existing beliefs. Obviously, the chances of initial success increase to the extent that one's conversation partners are familiar and they share knowledge about the topic. The chances of eventual success increase to the extent that there are opportunities for trial-and-error learning. These include receiving prompt, unambiguous feedback and incentives for improved understanding (e.g., feeling free to admit being confused or having misspoken).

These conditions are not always achieved, even with long-time friends and conversation partners. Official communications often face much less favorable conditions. Those bearing the duty to inform may know a topic inside-out, while their audience knows little, sometimes not even enough to appreciate the importance of attending to the issues. Beyond their differential familiarity with the specific topic, communicators and audience may come from different linguistic communities, reflecting their professional training, socioeconomic status, analytical orientation and even native language. These differences may also restrict their willingness to express concern, confusion or irritation to one another, as well as

3. For good sources for discussions of conversational norms, see H. Paul Grice, *Logic and Conversation*, in *The Logic of Grammar*, 64-75 (Donald Davidson & Gilbert Harman eds., 1976). See generally Nibert Schwartz, *Self-Reports: How the Questions Shape the Answers*, 54 *Am. Psychologist* 93 (1999) (explaining how the wording, format and context of research questions can influence research results).

the pace with which understanding increases, even when they do express these feelings.⁴

The learning process is further slowed (or stalled completely) when there is no direct contact between the parties—as can happen with the designers of chemical warning labels, public health pamphlets, patient package inserts, equipment instructions, website privacy notices and the like. There may be no evaluation at all or nothing more than sporadic reports with unclear sampling biases (e.g., calls to an 800 number, problems that happen to reach a surveillance system). Whatever evidence is collected still may not make it back to the communication designers, either at all or in time for them to learn very much. Even when catastrophic failures reach the courts or news media, the message is often garbled (sometimes deliberately). Moreover, the attribution of failure is a difficult task with complex systems. Inadequate communications may be the breaking point for systems that are so poorly designed that no message could have prevented disaster. They are a readily visible target for criticism, much in the way that “operator error” can be. Even when communications are properly held accountable, the lesson may not be very specific. It may be just “do better” or, even worse, “In the future, cover yourself by saying everything that could possibly be relevant.”

Hiding known problems or uncertainties cannot be condoned, whether they pose material risks or reduce the value of a product or procedure. However, saying everything may have little more practical value than saying nothing. Unless the list is fortuitously short, such a “core dump” violates the norms of communication by failing to focus on what the audience most needs to know and can process in a limited time. It may violate those norms further if the desire for technical precision overrides the desire for comprehensi-

4. For general sources on the gaps between expert and lay communities see Baruch Fischhoff, *Cancer Risk Communication: What We Know and What We Need to Learn*, 25 J. Nat'l Cancer Inst. Monographs 7 (1999) [hereinafter Fischhoff I]; Baruch Fischhoff, *Communicate Unto Others. . .*, 59 Reliability Engineering & Sys. Safety 63 (1998) [hereinafter Fischhoff II]; National Research Council, Committee on Risk Characterization, Commission on Behavioral and Social Sciences and Education, *Understanding Risk: Informing Decisions in a Democratic Society* (Paul C. Stern & Harvey V. Finberg eds., 1996); Baruch Fischhoff, *Risk Perception and Communication Unplugged: Twenty Years of Progress*, 15 Risk Analysis 137 (1995); William Leiss & Christina Chociolko, *Risk and Responsibility* 34-38 (1994); National Research Council, Committee on Risk Perception and Communication, *Improving Risk Communication* (1989) [hereinafter National Research Council I].

bility. Such an imbalance may reflect organizational processes as well as legal ones. Creating a product requires technical expertise, but not necessarily communication skill. The latter may be an afterthought, involving low-status individuals, asked to paper-over whatever problems the technical specialists failed to resolve. In that way, their role would be little different than that of other "human factors" experts in many design processes.⁵

Communication specialists themselves might be faulted if they failed to translate their expertise into terms compatible with the frame of reference for subject matter specialists. Living in largely separate worlds would contribute to such a gap, as would the qualitative nature of many social science theories. They predict the relative likelihood of behavior in different circumstances, rather than absolute performance levels. Even the rancorous debate over the extent of human rationality seldom addresses the question of what level is adequate in specific circumstances.⁶ Nonetheless, the social sciences offer tools that can direct and evaluate efforts to inform. Although they draw on general principles, these tools respect the details of specific particular settings. The remainder of this article is devoted primarily to three worked examples, drawing on somewhat different methods and addressing somewhat different contexts. The first considers medical informed consent, the second product warning labels and the third emergency systems. Each example focuses on the critical first step of the process outlined above: identifying information needs. It then sketches the behavioral research needed to establish what people know already, to design appropriate communications and to evaluate their adequacy.

INFORMED CONSENT FOR MEDICAL PROCEDURES⁷

In some jurisdictions, physicians are held to a *professional* standard: they need to say what their peers say. Although they

5. For good sources on design failures, see Donald A. Norman, *The Design of Everyday Things* (1990); Thomas K. Landauer, *The Trouble With Computers: Usefulness, Usability, and Productivity* 7, 128-40, 246 (1995); Stephen M. Casey, *Set Phasers on Stun: And Other True Tales of Design, Technology and Human Error* (1993).

6. For a recent, relatively nonpartisan summary, see Keith E. Stanovich, *Who is Rational: Studies of Individual Differences in Reasoning* (1999).

7. See Jon F. Merz, *Toward a Standard of Disclosure for Medical Informed Consent: Development and Demonstration of Decision-Analytic Methodology*

pool the judgments of a community, professional standards can also entrench flawed practices. That risk may be particularly large when there are few opportunities for systematic feedback and evaluation. Other jurisdictions have a *materiality* standard: physicians must say whatever is "material" to their patients' decisions. One way to implement this demand is to provide a laundry list of possible side effects. As in the pasta sauce ad, everything that one could possibly want is "in there," somewhere. However, that form of assurance may be of little value to patients—whose time, energy and cognitive capacity are all limited.

If materiality is interpreted as focusing on what people most need to know, then it might be operationalized in *value-of-information analysis* terms.⁸ That is, information is material to the extent that receiving it affects the expected utility of recipients' choices. These analytical procedures are typically applied to the decisions faced by individuals (with the wherewithal to command such attention). That requires eliciting their personal beliefs and values, regarding possible consequences of possible actions. The impact of additional information can be evaluated relative to this baseline (considering the costs of its acquisition, when the individual would bear them). For communications directed at a broad audience, that evaluation must consider the impacts aggregated over individuals like those who would receive it. Table 1⁹ shows the results of such an analysis, applied to a common medical procedure.

Carotid endarterectomy involves scraping out the artery leading to the brain. It can reduce the risk of stroke for patients with arteriosclerosis there. However, many things can go wrong, as seen in the list of Table 1, which includes only the most serious ones. That many things would be a lot to consider, especially under the stress of a life-threatening illness. These risks must be balanced against the possible positive consequences of the surgery (not shown in Table 1), namely, increased quality and quantity of life.

(1991) (unpublished Ph.D. dissertation, Carnegie Mellon University) (on file with author). For a summary, see Jon F. Merz et al., *Decision-Analytic Approach to Developing Standards of Disclosure for Medical Informed Consent*, 15 J. Products & Toxics Liab. 191 (1993).

8. See Robert T. Clemen, *Making Hard Decisions: An Introduction to Decision Analysis* 352, 358, 400-01 (1991); Howard Reiffa, *Decision Analysis: Introductory Lectures on Choices Under Uncertainty* 42-47 (1968).

9. See *infra* app., tbl.1.

The analytical results in Table 1 reflect one way to set information priorities. It uses Monte Carlo procedures to create a hypothetical population of patients, for all of whom the surgery would be a rational choice were there no risks (and were money no object). These patients vary in their physical condition, represented by probability distributions over possible consequences (indicating the expected variation in their response to the surgery). They also vary in their values, represented by distributions of utilities for those consequences. The Monte Carlo procedures create individual patients by sampling values from these distributions.¹⁰ Each patient is characterized by a combination of physical states and personal values. Standard procedures¹¹ are used to calculate the expected utility of the surgery decision for each such patient, ignoring all risks.¹² By definition, it is positive because these patients are all better off with the surgery. The expected utility is recalculated, including knowledge of the probability of a possible consequence, as estimated by medical research. The materiality of that information is captured in how much it reduces the expected utility of the surgery. If it changes from positive to negative, then the surgery is no longer recommended. The most important information is, arguably, that regarding the risk that would make the most patients decline the surgery.

In the example of Table 1, about 15% such patients should decline the surgery, upon learning the probability of immediate death.¹³ Another 5% should decline, if told the risk of iatrogenic stroke.¹⁴ An additional 3% should be dissuaded by hearing the risk of facial paralysis.¹⁵ Thus, although many other side effects are possible, few would affect many choices. In communication terms, although the set of potentially relevant facts is large, the set of critically relevant ones is small.

Conveying those facts means ensuring that recipients understand both the probability and the nature of each event. Some will

10. *See id.*

11. *See id.*

12. Expected utility for the surgery equals the sum of the expected utility for each possible consequence, which is equal to the product of its probability and utility.

13. *See infra* app., tbl.1.

14. *See id.*

15. *See id.*

be easier than others.¹⁶ In this example, the probabilities of the three focal side effects are large enough to be readily comprehended (rather than, say, thousandths of a per-cent). Moreover, whether they occur is resolved at one time, avoiding the difficulty that people have in seeing how risks accumulate through repeated exposure. Furthermore, given even rudimentary knowledge of the surgery, it is not hard to imagine these events occurring, so that patients can create a mental model that affords meaning and credibility to the statistical information. Thus, given what is known about the strengths and weaknesses of lay judgment under uncertainty, these should be relatively comprehensible probabilities.

The nature of the two top side effects (death and stroke) should be familiar, especially to candidates for this procedure, who face these possibilities already. (Regarding the meaning of death, there may not be that much that a medical professional could add in any case—beyond a description of the speed and pain of the immediate circumstances.) Thus, even a limited communication opportunity might allow focusing on what the third side effect (facial nerve paralysis) is like.

The example in the box assumes patients who know nothing about the probabilities of the possible outcomes. That seems reasonable for an unfamiliar surgery. For patients with prior beliefs, the analysis would consider how different facts would update those priors. Those priors could be elicited directly or derived theoretically. For example, reliance on the availability heuristic should lead to underestimating the probability of events that have never been mentioned; reliance on the representativeness heuristic might lead to underestimating risks that do not seem like natural

16. For reviews of research into understanding and communicating risks, see Fischhoff I, *supra* note 4; Jon D. Hanson & Douglas A. Kysar, *Taking Behavioralism Seriously: The Problem of Market Manipulation*, 74 N.Y.U. L. Rev. 630 (1999) [hereinafter Hanson & Kysar I]; Jon D. Hanson & Douglas A. Kysar, *Taking Behavioralism Seriously: Some Evidence of Market Manipulation*, 112 Harv. L. Rev. 1420 (1999) [hereinafter Hanson & Kysar II]; Baruch Fischhoff, *Risk Perception and Communication*, in *Oxford Textbook of Public Health* 987-1002 (Roger Detels et al. eds., 1997); Howard Leventhal et al., *Illness Cognition: Using Common Sense to Understand Treatment Adherence and Affect Cognition Interactions*, 16 *Cognitive Therapy & Res.* 143 (1992); National Research Council I, *supra* note 4; Paul Slovic, *Perceptions of Risk*, 236 *Science* 280, 280-85 (1987).

outgrowths of the procedure.¹⁷ (Facial paralysis might qualify on both grounds.)

In either case, the analysis creates a *supply curve*, showing the optimal order for providing new facts. That order would change if some important facts proved too hard to communicate. De-emphasizing them saves recipients' time—while acknowledging that less overall understanding is possible. The order should also change if some facts proved redundant, so that those patients who know one fact can predict the others. With the sort of artificial tasks presented in psychological experiments, any two features can appear together (e.g., the sizes and probabilities of the gains and losses in lab gambles), allowing no such efficiencies. However, when evaluating real events, patients may already have many beliefs and be quick to infer more. If they guess right, even a short description may communicate a lot.

Thus, efficient pursuit of this strategy would require assessing the beliefs that individuals bring to the task, regarding both the outcomes and the processes that lead to them. The search for such cognitive connections has prompted the study of lay *mental models* for many domains.¹⁸ A typical finding is that people organize diverse facts into highly flexible templates (e.g., how the circulatory system works, how the body processes toxins, how hazardous chemicals flow through groundwater, how risks mount up through repeated exposure). Most such studies contrast observed behavior with a normative standard. For decisions under uncertainty, with complex, loosely bounded problems, that standard can be captured in an *influence diagram*, showing the factors determining the probabilities appearing in the associated decision tree.¹⁹ The contrast between lay beliefs and these models has guided the development of communications on many topics, including radon, climate

17. See Judgment Under Uncertainty: Heuristics and Biases (Daniel Kahneman et al. eds., 1982).

18. See, e.g., Phillip N. Johnson-Laird, *Mental Models: Towards A Cognitive Science Of Language, Inference and Consciousness* (1983); Frederic C. Bartlett, *Remembering: A Study In Experimental and Social Psychology* (1961); William B. Rouse & Nancy M. Morris, *On Looking Into the Black Box, Prospects and Limits in the Search for Mental Models*, 100 *Psychol. Bull.* 349 (1937); Edward C. Tolman, *Purposive Behavior in Animals and Men* (1932).

19. See Clemen, *supra* note 8; Baruch Fischhoff et al., *Adolescent Vulnerability: A Framework For Behavioral Interventions*, 7 *Applied Preventative Psychol.* 77, 80 (1998); Robert A. Howard, *Knowledge Maps*, 35 *Mgmt. Sci.* 903, 903-05 (1989).

change, oil spills, electromagnetic fields, mammography, HIV/AIDS, other sexually transmitted diseases and nuclear energy in space.²⁰ These procedures are available for medical informed consent.²¹

PRODUCT WARNING LABELS²²

A necessary condition for an efficient market place is that potential users of a product be able to understand its risks and benefits well enough to determine whether buying it is in their own best interests. When those conditions are lacking, a case can be made for regulatory protection. That may happen as a result of deceptive packaging or advertising.²³ However, it can also occur when people are left to their own devices, with no effort being made to address their "naïve" misunderstanding. Products may just seem safer or more beneficial than they actually are. In the absence of remedial information, people will, in effect, mislead themselves.

Product warning labels often bear the onus of the duty to inform. If they effectively communicate an acceptable level of risk, then they can free individuals to use products that bring them desired benefits, while avoiding any extra costs of regulation that might be passed on to them. Where individuals can exercise control over their exposures, appropriate information can help them reduce their own risk (e.g., by using protective equipment or procedures), perhaps bringing it into the acceptable-risk range, perhaps increasing their net benefit from an already acceptable product. Evaluating the adequacy of labels means estimating the risks that will be experienced by people expected to rely on them, making realistic assumptions about human behavior. There is a great deal of

20. See Fischhoff II, *supra* note 4, at 69. See, e.g., Granger Morgan et al., Risk Communication: The Mental Models Approach (forthcoming 2001) (on file with author); Baruch Fischhoff, *Diagnosing Stigma*, 59 Reliability Engineering and Sys. Safety 47 (1998); Ann Bostrom et al., *Characterizing Mental Models of Hazardous Processes: A Methodology and an Application to Radon*, 48 J. Soc. Issues 85 (1992).

21. See Fischhoff I, *supra* note 4, at 7.

22. See generally Donna M. Riley et al., *Modeling Methylene Chloride Exposure-Reduction Options For Home Paint-Stripper Use*, 10 J. Exposure Analysis & Env'tl. Epidemiology 240, 240-50 (2000) (evaluating a general methodology for the effectiveness of behavioral interventions for the risk of exposure to dangerous household chemicals).

23. See generally Hanson & Kysar I, *supra* note 16, at 630 (discussing market manipulation and the need for corrective legal devices); Hanson & Kysar II, *supra* note 16, at 1420 (presenting empirical evidence of market manipulation).

research literature on what draws people's attention to labels.²⁴ For example, studies have found that consumers are most likely to read the first few sentences at the top of the back panel²⁵ or in the directions section.²⁶ Bolded words add emphasis and draw attention.²⁷ Such studies form one input to estimating the risks achieved with particular warning labels.

Household chemicals represent one large domain in which consumer understanding can be critical and modeling of exposure is possible. Figure 1²⁸ shows one set of results, produced by a model predicting cumulative exposures to methylene chloride, the active ingredient in most paint stripper formulations. Such exposures have been related to carcinogenicity and suspected of other effects; peak exposures can lead to heart attacks, through the build-up of carbon monoxide in the work area.²⁹ They can be estimated with the same model (not shown here). The model was initially developed from physical principles (of air circulation and chemistry) and then calibrated under laboratory conditions.³⁰ Assumptions about the effects of plausible user behavior were added, incorporating results from twenty interviews conducted at a home improvement center.³¹

This particular example reflects a typical job, conducted in a small workroom. The model is, however, general enough to accommodate other jobs, rooms, chemicals and work practices. The declining lines in the figure show the "best buys" in exposure reduction, as those emerged from analysis of various possibilities. They show the marginal benefit of each step for reducing exposure, as well as their combination. The gray lines show full compliance,

24. See generally Selections from Human Factors and Ergonomics Society Annual Meetings 1980-1993 (Kenneth R. Laughery, Sr. et al. eds., 1994) (compiling a number of papers on different types of warnings and their impact on consumers).

25. See Keyla Friedmann, *The Effect of Adding Symbols to Written Warning Labels on User Behavior and Recall*, 30 Hum. Factors 507, 514-15 (1988).

26. See J. Paul Frantz, *Effect of Location and Procedural Explicitness on User Processing of and Compliance with Product Warnings*, 36 Hum. Factors 532, 543-45 (1994).

27. See Judy Edworthy & Austin S. Adams, *Warning Design: A Research Perspective* 25-46 (1997).

28. See *infra* app., fig.1.

29. See Agency for Toxic Substances and Disease Registry, *Methylene Chloride Toxicity*, 47 Am. Fam. Physician 1159, 1161 (1993).

30. See John R. Girman et al., *Considerations in Evaluating Emissions from Consumer Products*, 21 Atmospheric Env't 315, 315-20 (1987).

31. See *id.*

while the dark lines show partial compliance. Thus, in this small room, full compliance with opening windows and taking breaks would be equally effective. However, partially opening windows is much better than partially taking breaks. Full breaks add something to opening windows, while partial breaks do not. Adding a fan makes a big difference, even with partially opened windows. Thus, if (small room) consumers cannot realistically be expected to take diligent breaks, then that strategy should not be emphasized. Rather, instructions should stress ventilation, where imperfect efforts can make a big difference. (The flammability of some formulations of paint removers does mean that this message would have to specify a non-sparking fan.)

What users will do, in the absence of instructions, is an empirical question which can be answered in various imperfect ways. In principle, observing users' behavior should provide the most realistic estimates. However, such observation can be *reactive*, with people behaving differently (and probably more cautiously) when they know that others are watching. Interviews are another option, facing some of the same measurement issues. For example, Kovacs, Small, Davidson and Fischhoff³² found that fewer than 5% of subjects even looked at the precautionary statement on the back label of a chemical cleaner in an experimental setting; nonetheless, in a post-experiment questionnaire, 18% reported having read the label during the experiment, while 76% reported that they "normally read" labels.³³ Nonetheless, carefully collected data, following the norms of social research and attempting to reduce reactivity, can discipline speculations. Moreover, such research can provide some protection against self-serving desires to envision users as particularly sloppy or savvy (e.g., to justify regulation or deregulation, respectively).

In lieu of such data, one can still get some idea of exposures by presuming different label-reading patterns. Figures 2a-d³⁴ follow this strategy. They show the expected inhalation dose of methylene chloride, for individuals performing a common paint-stripping task, in a medium-sized room with moderate ventilation. Each fig-

32. See Daniel C. Kovacs, et al., *Behavioral Factors Affecting Exposure Potential for Household Cleaning Products*, 7 J. Exposure Analysis and Env'tl. Epidemiology 505 (1997).

33. See *id.*

34. See *infra app.*, figs.2a-d.

ure makes different assumptions about users' reading habits. Each curve refers to the label of a product taken off the shelves of a home improvement store. Figure 2a assumes that users read the first five items on the labels of six different products (taken from the shelves of a local hardware store), and then follow those directions perfectly. Clearly, Product B does a much better job than the others, for users with these reading habits. That advantage vanishes for users who read only the text emphasized on a label (Fig. 2b) or only the directions (with all labels performing equally poorly) (Fig. 2c). For those (rare?) users who read everything, there is virtually no exposure at all with product A; the labels for B, D, and E produce exposures like those for B in the figure; products C and F perform no better (Fig. 2d).

The analyses of Figure 2³⁵ assume complete compliance with what users read. How far that happens will depend on the details of the design. In addition to rendering these instructions clear and persuasive, labels might increase compliance by communicating the ineffectiveness of the gloves and breathing aids that many people use. Those provide little protection; indeed, many gloves are dissolved by the solvent. Such measures might even increase exposures, if they create a false sense of security, encouraging users to remain in work areas longer than they otherwise would. Doing less of one (ineffective) thing might encourage doing more of another (effective) one, for individuals willing to invest a fixed amount of money or energy in risk management. Instructing consumers about the properties of different glove materials will be difficult. As a result, if the use of gloves is to be improved, an engineering or marketing solution may be needed. For example, appropriate gloves might be packaged together with the chemical, while inappropriate gloves are explicitly labeled "not suitable for paint stripping." An even better bit of advice might be advocating the use of goggles. Those currently on the market effectively protect against splatter injuries. In addition to citing the frequency of such accidents, motivating instructions might ask consumers to examine the splatter patterns on their own work clothing, as well as noting that these goggles are suited for multiple use (unlike the dissolving gloves).

35. *See id.*

How well any of this will work is an empirical question. Arguably, relevant data *should* be collected by those who advocate for fault regulatory or voluntary risk-management practices. Where task-specific data are lacking, one should rely on research-based principles, rather than on mere supposition. Those predictions of behavior should be interpreted in the context of a formal model, relating them to exposures, showing just what risks are associated with the practices. Some failings matter a lot less than others. Such analyses allow juries, regulators, politicians and others to decide whether realistic use patterns create an acceptable level of risk. They allow producers and merchants to decide whether they want to live with those exposures, even if they are deemed legal or still want improved designs.

EMERGENCY SYSTEMS³⁶

Public and private officials often bear a special duty to inform, when otherwise benign (or beneficial) systems dramatically misbehave. Expressions of that duty can be seen in the emergency warning procedures of industrial facilities, fire departments, commercial airlines and disaster management agencies, among others. The effectiveness of these procedures depends on how quickly warnings reach their intended audience, and how well they are understood and followed. These, too, are empirical questions, whose answers require the ability to predict human behavior in specific settings. Figure 3³⁷ shows a formal model designed to do that for *Cryptosporidium*, a protozoan parasite that can infect public water supplies.³⁸ It was responsible for a massive outbreak in Milwaukee during 1994, which killed about 100 people and sickened some 400,000.

Cryptosporidium, found in most surface waters, is shed through the feces of infected humans and animals in the form of oocysts—spheroidal, environmentally resistant eggs about three to

36. The research reported here is presented in full in Elizabeth Casman et al., *Integrated Risk Model of a Drinking Waterborne Cryptosporidiosis Outbreak*, 20 *Risk Analysis* 493 (2000).

37. See *infra* app., fig.3.

38. See Charles N. Haas et al., *Quantitative Microbial Risk Assessment* 150-51 (1999).

five microns in diameter.³⁹ It enters the water supply through human sewage effluent discharges and fecally contaminated storm water runoff. Most forms of modern drinking water treatment, such as sand filtration and chlorination, cannot fully remove or deactivate oocysts in the water.⁴⁰ As a result, *Cryptosporidium* occasionally finds its way into tap water. Its symptoms appear after a one to seven day incubation period, and include nausea, vomiting, diarrhea, stomach cramps and a low-grade fever. Although there is currently no medicine to treat the disease, many infected individuals exhibit no symptoms, or have them pass within two weeks. However, the disease can be fatal in immunocompromised persons, such as those with AIDS, for whom the death rate can be over 50%.⁴¹

The United States Environmental Protection Agency (EPA) considers *Cryptosporidium* to be one of the most serious problems in United States drinking water today [EPA 815-F-98-0014]. Recent outbreaks in the United Kingdom have led to additional regulations.⁴² In 1998, when *Cryptosporidium* oocysts and *Giardia* cysts were detected in the drinking water of Sydney, Australia, media reports led millions of city and regional residents to become angry, fearful and distrustful of their drinking water.⁴³ Many claimed to have become ill from drinking Sydney tap water, although not a single case of cryptosporidiosis or giardiasis was actually confirmed. In fact, some environmental consultants now believe that there were no extra oocysts and cysts in the water at all. Rather, poor quality control had produced a "false positive" detection. The episode cost tens of millions of dollars for the ensuing public inquiry and liability settlements, caused the resignations of both the Chairman and the Managing Director of the Sydney

39. See generally Ronald Fayer, *Cryptosporidium* and *Cryptosporidiosis* (1997) (comparing and compiling research conducted concerning *cryptosporidium* and *cryptosporidiosis*).

40. See Michelle M. Frey et al., *Cryptosporidium: Answers to Questions Commonly Asked by Drinking Water Professionals* 29-35 (AWWA Research Foundation and American Water Works Association eds., 1997).

41. See Joan B. Rose, *Environmental Ecology of Cryptosporidium and Public Health Implications*, 18 *Annual Review of Public Health* 135 (1997).

42. See Frey, *supra* note 40.

43. See generally Steve E. Hrudey, *The Sydney Water Crisis* (1999), available at http://www.ucalgary.ca/~wleiss/news/sydney_water_crisis.htm (last visited Dec. 18, 2000) (describing media attention and criticism of handling 1998 water crisis in Sydney, Australia).

Water Corporation and set off proposals to subject the Sydney Water Corporation to greater ministerial control.⁴⁴

Figure 3 shows the complex of physical, biological and social factors that determine the extent of outbreak risk. It has the form of an influence diagram. In it, each node represents a variable. Two nodes are connected if knowing the value of one (at the tail of the arrow) improves predictions for the value of the other. Thus, for example, the extent of utility awareness of a potential outbreak predicts the chances of special studies being conducted or a joint task force (of relevant agencies) being created. Estimating these risks requires inputs from microbiology (for dose-response relationships), civil engineering (filtration and testing), ecology (land use), communications (attention to "boil water" notices) and psychology (perceived risk, actual response), among other disciplines. The computational version of this model specifies values for each variable and dependency, as experienced at a particular site. In some cases, those estimates are extracted from empirical studies; in others, they are but expert judgments.

This model was created as the integrating core of a project focused on reducing cryptosporidium risks through better communication with water consumers. However, running it revealed that current testing procedures are so ineffective that an outbreak is likely to have passed (or at least peaked) before its source is detected. Basically, it takes too long to culture the parasite. As a result, even if the communication system worked perfectly and consumers did exactly as told, an emergency management system that relied on "boil water" notices would fail to protect the most vulnerable. Under these circumstances, vulnerable populations require other forms of protection, such as routine provision of bottled water. The resources available for notification might be better spent on developing and installing improved detection procedures.

Were such detection mechanisms in place, the model predicts that the quality of communications should make a difference in reducing health risks. For example, if the institutional coordination mechanisms shown in the figure work as planned, they could get a message out quickly and consistently, increasing its credibility. The content of the message would need to convey (a) that all public

44. See Jennifer L. Clancy, *Sydney's 1998 Water Quality Crisis*, 92 J. AWWA 55, 62, 64 (2000).

water is potentially affected, (b) that all uses pose danger (even small ones, like tooth brushing), and (c) what boiling water entails. As examples of the kinds of misunderstandings that are possible, interviews with Pittsburgh-area residents found such beliefs as, "I'd let the tap run a couple of hours, and then it'll be clear," and, "I think only cold water would have to be boiled." Generally speaking, HIV+ respondents had greater awareness and understanding of these issues than did others, even though they were predominantly sampled from areas that had had waterborne disease problems.⁴⁵

Although not that helpful for managing immediate emergencies, current testing procedures might still produce results that help with managing future ones. A definitive (forensic) diagnosis of "what hit them" in a past outbreak might help citizens to decide what to do about policies affecting future risks (e.g., regulating land use, investing in filtration systems).

EVALUATING COMMUNICATIONS

In a sense, the details of these examples are immaterial. Even were these three topics of specific interest, a real application would require updating their estimates to accommodate the latest research regarding the model's components, as well as being tailored to behavioral observations with individuals like those in the target audience. Rather, the examples were chosen to demonstrate the kinds of conclusions that are possible. These include potentially discovering that vital resources are invested in communicating facts of little practical value, that critical facts are missing entirely from communications intended to protect recipients, that chosen facts are not formulated comprehensibly or that communication is pointless in a system that is fundamentally unsound. Where health and safety (or even "just" money) are at stake, such analyses might be considered the "standard of care," to which those exposed are entitled. Failing to conduct such systematic evaluations might be taken as evidence of "negligence," just as appropriate analyses might be taken as evidence of "due diligence." These terms are used here in an informal sense, with an invitation to the

45. See F. Wu et al., *Cryptosporidium* Risk Communication: An Analysis of What People Know, and What They Need to Know (unpublished manuscript) (on file with author).

legal community to consider the status of these claims in tort and regulatory law.

Such analyses are not the norm today. Among other things, they require uncommon coordination of disciplines and collection of evidence. Nonetheless, the additional effort might be acceptable to risk managers, insofar as it provides a procedurally predictable way to address a perennial problem. Responsible parties might be willing (even eager) to make the investment, if it conferred protection in the court of law or the court of public opinion. Even without those threats, risk managers might be happy taking better advantage of current natural and social science in accomplishing their life's work.

APPENDIX

TABLE 1

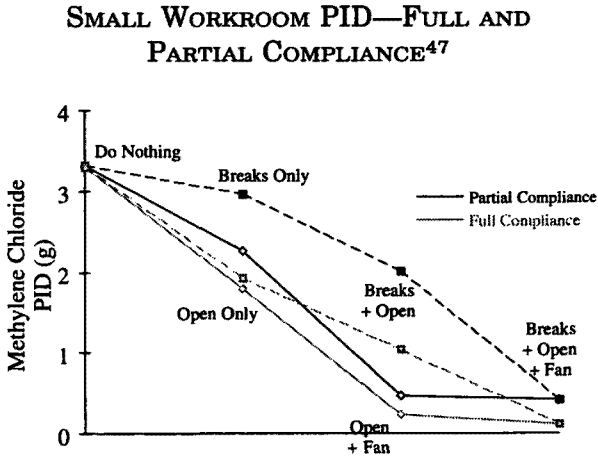
A MATERIALITY STANDARD FOR PRIORITIZING
INFORMATION FOR MEDICAL
INFORMED CONSENT⁴⁶

The percentage of a simulated patient population that would decline
carotid endarterectomy, upon learning of each risk.

Risk	Percentage declining (standard deviation)
Death	15.0 (0.3)
Stroke & neurological deficit	5.0 (0.2)
Facial Nerve paralysis	3.0 (0.2)
MI (myocardial infarction)	1.1 (0.1)
Lung damage	0.9 (0.06)
Headache	0.8 (0.1)
Resurgery	0.4 (0.03)
Tracheostomy	0.2 (0.03)
Gastrointestinal upset	0.09 (0.1)
Broken teeth	0.01 (0.01)
Liver damage	0.01 (0.01)
Parotiditis	0.01 (0.01)
Kidney dysfunction	0.01 (0.01)

46. Merz, *supra* note 1, at 231-64.

FIGURE 1

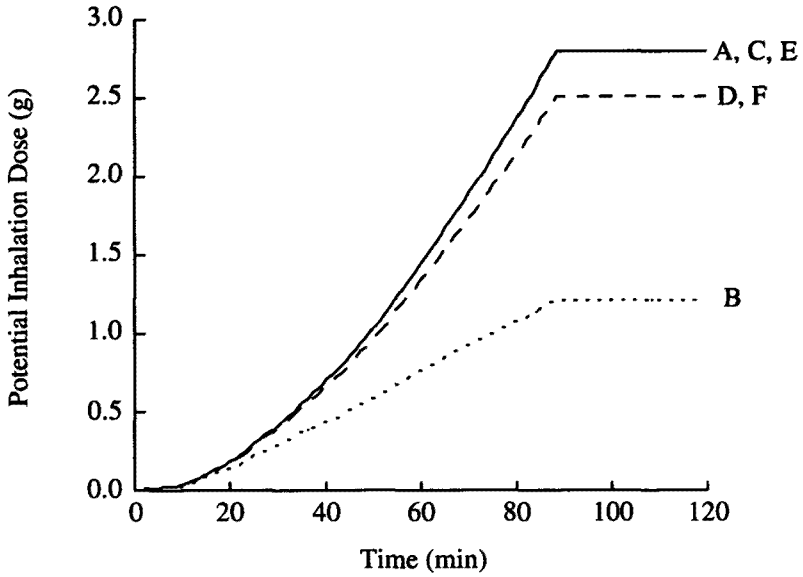


PID = Potential Inhalation Dose, a measure of cumulative exposure, in terms of grams inhaled.

47. Donna M. Riley, *Human Factors in Exposure Analysis for Consumer Paint Stripper Use* (1998) (unpublished Ph.D. Dissertation, Carnegie Mellon University) (on file with author).

FIGURE 2A

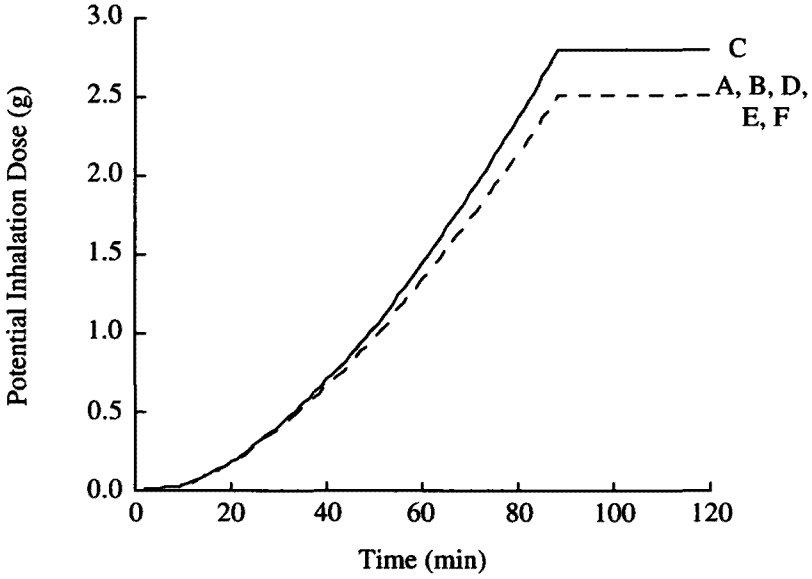
READING FIRST FIVE POINTS (SCENARIO 1)⁴⁸



48. *Id.*

FIGURE 2B

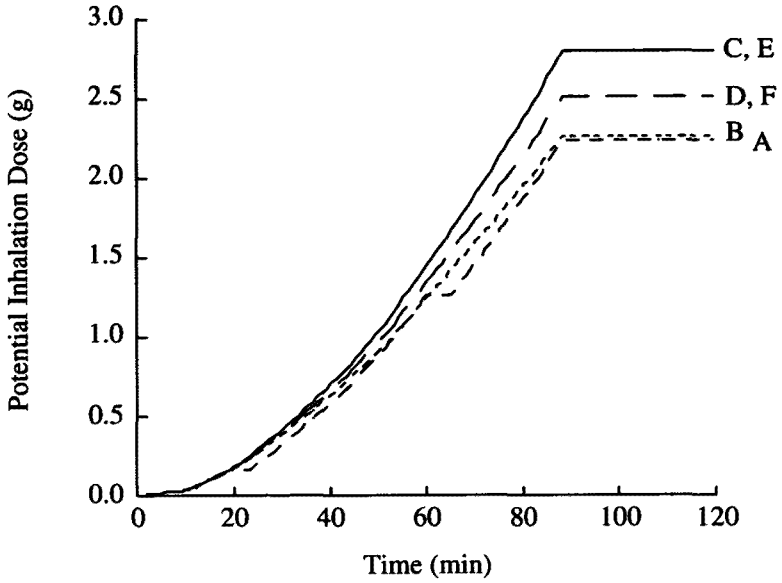
READING EMPHASIZED TEXT (SCENARIO 2)⁴⁹



49. *Id.*

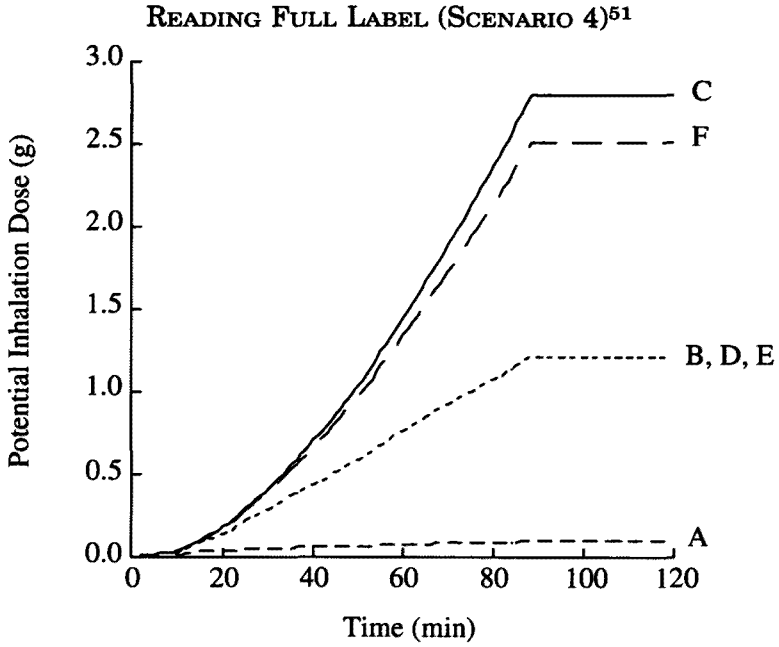
FIGURE 2C

READING DIRECTIONS ONLY (SCENARIO 3)⁵⁰



50. *Id.*

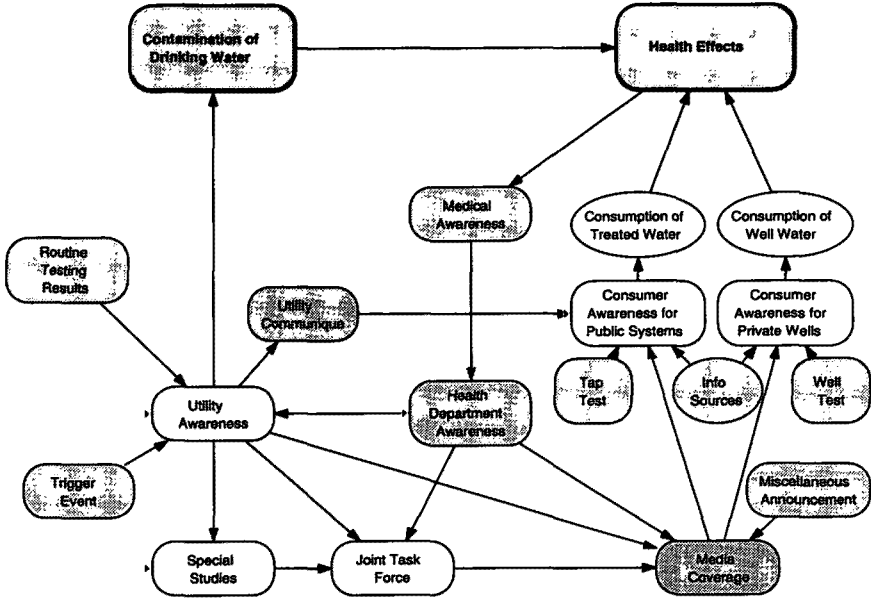
FIGURE 2D



51. *Id.*

FIGURE 3

EXPERT MODEL OF WATERBORNE
CRYPTOSPORIDIOSIS OUTBREAK⁵²



52. Elizabeth Casman et al., *supra* note 36.

