COMMUNITY RISK PERCEPTION: A PILOT STUDY

Branden B. Johnson and Bradley Baltensperger

Department of Social Sciences
Michigan Technological University

ABSTRACT

Hazard identification studies have tended to test only one explanatory model at a time. Preliminary results of a pilot study intended to compare the relative explanatory power of two personality, two bounded rationality, and three "social construction of risk" models of hazard perceptions are reported.

KEY WORDS: risk perception, hazard perception, personality, bounded rationality, social marginality, community

Hazard perception studies have generally assumed concerns about potential hazards are based on (1) emotion and personality, (2) bounded rationality, (3) "objective" reality, (4) cognitive biases. Recently, "social construction of risk" theories have been proposed as well (Johnson and Covello, forthcoming). Eventually, hazard identifications will be seen as some combination of these factors. But at present most researchers test hypotheses appropriate to only one model at a time; the relative validity of different hazard identification models cannot be examined through this approach. This paper is intended to stimulate comparative testing of models and hazards by reporting preliminary results of a pilot study done by the authors. Although the results are not conclusive, they suggest lines of attack for future research.

RESEARCH DESIGN

Because this was a pilot study, with limited money and time, we focused our attention on models which could be examined in a simple and straightforward fashion: two personality models (risk arousal and locus-of-control), two bounded rationality models (knowledge and experience), and three social construction of risk models (social marginality, political views, and community connectedness). All statistical relationship between variables reported below are significant at the .05 level or better.

The study site was the Torch Lake area of the Keweenaw Peninsula in Michigan's Upper Peninsula. Tumors have been found in Torch Lake fish, the state department of health advised against eating lake fish in 1983, and the lake has been placed on Superfund lists pending research results on the tumors' causes (possibly copper tailings) and human health implications. Other hazards include heavy snow (15-foot annual average), nuclear waste (a nearby area is being considered as a national high-level waste repository), and group homes for the mentally retarded. Residents' exposure to automobile, prescription drug, airplane, and cigarette hazards is much like that of other Americans; they are probably less exposed to nuclear power plant hazards (none is located within about 350 miles).

The population of interest was Torch Lake area registered voters, 2293 (87%) of the 2649 eligible adults. Telephone interviews with a random sample of 127 were completed by student interviewers in June, 1985. From that sample, 47 respondents were selected for face-to-face interviews conducted by the authors from July 24 to August 19. Our sample was somewhat biased toward the better educated: 1980 county high school completion rates were 61% for males and 65.4% for females; our overall figure was 89%. Our sample was comparable to the population in age and sex. Information on hazard knowledge and experience was collected almost entirely from the second sample; other variables were measured in both interviews.

RESULTS

Hazard Ratings. Respondents in the large sample were asked to rate the benefits, risks, and acceptability to society of eight items (see Table 1) on a scale from 0 (e.g., no benefit) to 9 (e.g., great benefit). Median benefit and acceptability ratings were high for automobiles, drugs, and airplanes, and low for cigarettes, nuclear and toxic waste facilities; the reverse was true for risk ratings. The relative rankings for five common hazards are similar to those obtained for perceived benefits and risks by Slovic et al. (1980). Benefits and acceptability ratings were positively correlated for all hazards: risks and acceptability were negatively correlated for all hazards except automobiles. Benefits and risks were also negatively correlated for all hazards.

Ratings for nuclear power plants and toxic waste disposal facilities were strongly correlated--benefits (r=.30), risks (r=.37), and acceptability (r=.62)--suggesting a dread dimension might have been tapped, as in Slovic et al. (1980). The correlations among automobile and airplane ratings (.46, .38, and .51) are plausible, since both were found to be familiar hazards by Slovic et al.

Risk ratings were elicited in both interview waves for three hazards, in order to test their reliability over the 4-11 week gap. Nuclear power risk ratings were moderately correlated (r=.40), but automobile ratings were not correlated (r=.08). To appropriately measure "experience" with snow in a heavy-snow area, we asked for risk ratings of "major winter storms" in the second interview instead of for "snow"--there was no correlation (r=.10) between them. It is striking that an emotion-laden issue like nuclear power appears to evoke stable risk ratings, whereas ratings of familiar hazards seem to fluctuate. The very prominence of nuclear power as an issue may have given people a chance to come to a firm conclusion--on whatever basis--about its risk. By contrast, automobiles and snow may be seen as just part of life rather than as explicit hazards, and so rating their risks is an unfamiliar task yielding volatile results.

There was a moderate correlation (r=.40) between assessments of trends in overall safety of life during the past 50 years and the next 50 years, suggesting an optimist-pessimist dimension. People who saw life as becoming less safe in the last 50 years were somewhat more likely to rate automobile risks high (r=.23). The less safe the future was expected to be, the higher the risks (r=.28) and the lower the benefits (r=-.18) and acceptability (r=-.19) of toxic waste facilities were rated; this again

TABLE 1

Hazard Rating

b Benefit-[b]				Benefit-[b]	Risk-
Item	Benefits[a]	Risks[a]	Acceptability[a]	Acceptability	Accep
tability	Risk				
Automobiles	9	4	9	.35***	.01
-.13					
Nuclear Power Plants	4	7	4	.64***	
-.44***	-.44***				
Prescription Drugs	9	4	7	.54***	
-.33***	-.22**				
Airplanes	9	3	8	.48***	
-.20**	-.20**				
Toxic Waste Disposal Facilities	5	7	4	.45***	
-.41***	-.38***				
Cigarettes	0	9	0	.39***	
-.15*	-.36***				
Group Homes	7	1	7	.42***	
-.37***	-.40***				
Snow	6	2	6	.51***	
-.32***	-.29***				

N=122-127

a Median ratings on a 0-9 scale (e.g., no benefit-great benefit)

b Pearson correlation coefficients

* $P \leq .05$

** $P \leq .01$

*** $P \leq .000$

suggests some "dread" dimension, though it is striking that nuclear power plants did not correlate significantly with future risk assessments.

Pearson correlations were calculated between automobile ratings and self-reported seatbelt use, cigarette ratings and self-reported smoking, and toxic waste disposal facility ratings and self-reported eating of Torch Lake fish. The only significant relationships were those between smoking and cigarette benefit (r=.46) and acceptability (r=.25) ratings. The low positive response (19.8%) to the question "Do you ever eat fish from Torch Lake?," and low seatbelt usage--on a four-point scale, 10.2% of 127 respondents said they "always" wore one, 18.1% said they did so "most of the time"--may have obscured any attitude-reported behavior correlations on these items.

These seatbelt use responses were collected just before the Michigan mandatory seatbelt use law went into effect (July 1, 1985). Responses from our sample of 47 to the same question after that date were highly correlated with the pre-law responses (r=.63); those reporting using belts "sometimes" or "never" dropped from 32 to 11 of 46. While post-law belt use was not significantly related to second-wave automobile ratings, it was correlated with fewer perceived benefits to automobiles (r=.37) and with support for the state mandatory-use law (r=.40).

<u>Personality</u>. Personality and emotion have been linked to hazard identifications by several researchers (e.g., Sims and Baumann, 1972; Simpson-Housley et al., 1978; Johnson and Tversky, 1983). Others have criticized this approach or had null findings (e.g., Schiff, 1977; Simpson-Housley et al., 1982; Brown et al., 1983a,b; De Man et al., 1984a,b). An "arousal-seeking" scale was constructed by Mehrabian and Russell (1974); we selected from it eight items oriented specifically to arousal from "risk" and asked respondents to rate their agreement with them on a 6-point scale.

Factor analysis identified three statements--all concerned interest in "frightening" or "dangerous" activities--loading highly (.68 to .79) on the first factor (which explained 23.2% of the observed variance). We conservatively used the sum of the responses to these three statements as our only measure of risk arousal. People "aroused" by risk were significantly more likely to find airplanes "acceptable," expect the future to be safer than the present, and favor local siting of a nuclear power plant, but the Pearson correlations were low (about .15). No other variables were significantly correlated with the "risk arousal" score, nor were automobile ratings correlated with agreement that "I enjoy driving very fast."

Locus-of-control (LOC) scales (Rotter, 1966) measure the degree to which people feel they exercise control over their lives. There may be three LOC factors: belief in chance, expectancy of control by powerful others, and perceived mastery over one's own life (Levenson, 1974). Our scale used 18 items from Levenson's 24-item scale. Behavior-specific LOC items may be more predictive of behavior than general ones (Huebner and Lipsey, 1981), so "getting cancer" and Levenson's "car accident" statements were added for comparison of specific and general LOC scales' Ability to predict automobile, nuclear, and toxic waste risk perceptions.

Factor analysis identified three factors which together explained 42.4% of the variance. Three statements in Factor 1 (with factor loadings greater than .7) tapped internal locus-of-control, three in Factor 2 tapped a "powerful others" dimension, and two in Factor 3 tapped a "chance" dimension. Summary scores for each LOC dimension were used as independent variables to predict hazard ratings; the highest Pearson correlations are reported below.

The more internally-oriented a person was, the more he or she was likely to oppose local siting of a nuclear waste facility (r=.21) and express an intention to move out of the community if one was built there (r=.25). Those attributing control to powerful others saw higher risks from airplanes (r=.17), a standard "involuntary" hazard, and said they would move out if a chemical waste facility was built locally (r=.26). Those who saw chance as ruling their lives were more likely to oppose a local group home and to say they would move if a local chemical waste disposal facility was built (r=.24).

Internalization of control over being in an automobile accident was correlated with finding automobiles riskier, less beneficial (r=.31) and less acceptable. A view that accidents are the other driver's fault was correlated with perceiving high automobile benefits (r=.24); scores on the chance-automobile statement were not significantly correlated with automobile ratings. Internalization of cancer causes ("Whether I get cancer depends mostly on my own actions") was correlated with favoring local siting of a nuclear power plant, nuclear waste facility (r=.30), or chemical waste facility, perceiving high benefits from nuclear power and low risks from toxic waste disposal facilities. Correlations for these "specific" LOC statements are slightly better than those for the overall scores.

Hazard Experience and Knowledge. "Bounded rationality" studies emphasize the individual's (limited) knowledge or experience of the hazard and of the range of coping actions as determining perceptions and behavior. Despite some empirical support for this model (e.g., Burton et al , 1978; Lichtenstein et al., 1978), there has been strong criticism of it (e.g., Hewitt, 1983; Sims and Baumann, 1983; Sorenson, 1983). Measures of knowledge of nuclear power were adapted for this study from Kuklinski et al. (1982). Knowledge questions were also formulated for nuclear waste, water pollution, hazardous chemical wastes, and automobiles. Experience variables were constructed for automobiles, snow, and water supply.

Lichtenstein et al. (1978) found that knowing someone who had died from the hazard was correlated with risk ratings. We found no such correlation for automobiles, or for how recently the respondent had been involved in an automobile accident, and reported personal injuries were too few to run a correlation. Being the driver in the most recent accident was confusingly correlated with rating automobile benefits lower (r=.36) and with opposing the new state mandatory seatbelt use law (r=.33). The correlation (r=.31) between the respondent having been in an automobile accident at some time and lower perceived risks is also counter-intuitive (unless experience teaches that accidents are not as bad as they are thought to be).

Most measures of experience with snow hazards (e.g., property or health damage) had too few positive responses to allow analysis. There was no correlation between the time since the remembered "worst year" for major winter storms locally and hazard ratings. There was a small negative correlation (r=-.26) between the time since a major storm last caused "serious problems" for the community and higher risk ratings for such storms.

Preliminary analysis of the summary knowledge scales revealed that the more knowledgeable people were about nuclear power, the lower they rated its risks (r=.15) and the more favorable they were to local siting of a nuclear plant (r=.17). Nuclear waste knowledge was not significantly correlated with toxic waste or nuclear waste facility ratings. Automobile knowledge was significantly correlated only with its acceptability rating (r=.17); other hazard ratings, including reported seatbelt use, were not correlated with this knowledge. Hazardous waste knowledge was negatively correlated with perceived "danger" from local water pollution (r=-.33), suggesting some association of degree of knowledge and concern about Torch Lake pollution. Our measure of water pollution knowledge was correlated with unwillingness to move out of town if a chemical waste disposal facility was built locally (r=.37). Knowledge appears somewhat important in hazard identifications, but its import varies by hazard.

Social Marginality. Some researchers have begun to develop "social construction of risk" theories which assume that hazard identifications are born of everyday social interactions (see Johnson and Covello, forthcoming). Rogers (1985:499) found that "women, the less educated, and particularly young adults [18-29] tend to estimate risk at higher levels and be less likely to find, at least nuclear, risks acceptable." He attributed this to these respondents' marginal location in the social structure. We included gender, education, and age among our socio-demographic variables, as well as income, employment, and marital status.

In contrast to Rogers' (1985) findings, neither age nor education was related to any hazard ratings. Women did rate nuclear power's risks higher (r=.24), as Rogers found, as they did the benefits of automobiles (r=.33) and airplanes (r=.32), but there were no other significant correlations with gender. Of the other indicators of social marginality, lower income was correlated only with high perceived risk from group homes (r=.21). Umemployment in the respondent's family during the past three years was correlated with perceived drug benefits (r=.25) and cigarettes' risk (r=.35), but negatively with cigarette acceptability (r=-.26). Current unemployment of the respondent correlated with lower perceived benefits (eta=.29) but higher acceptability (eta=.24) of airplanes. Unemployment also correlates not only with greater agreement that there is a local pollution problem (eta=.25), but also with favoring cleanup of local pollution even if it meant settling for somewhat higher unemployment (eta=.28)! Our results only partly confirm Rogers' marginality hypothesis for hazard identifications.

Political Variables. Starr (1985) contends that public acceptability of risks is dependent more on public trust in hazard managers than on quantitative measures of such risks. Political variables used in this study included participation in political activities, trust in various political actors, and political ideology.

These were not significantly correlated with most hazard ratings. Exceptions included a link between local electoral activity and perceived cigarette benefits (r=.23), and between self-reported conservative ideology and acceptability ratings for toxic waste disposal facilities (r=.25) and snow (r=.21). Ratings of government's ability to cope with nuclear power plant safety (N=47) were positively correlated with nuclear power's acceptability (r=.28), consistent with Starr's (1985) hypothesis that hazard acceptability is related to confidence in hazard managers. No significant correlation was found between local government ratings for coping with snow and automobile hazards and these hazards' ratings.

Community Connectedness. Community connectedness measures have been implicated in some hazard identifications (e.g., Preston et al., 1983; Fowlkes and Miller, forthcoming). Social interaction variables used in this study include membership in local organizations and various expressions of commitment to the community.

To our surprise, membership in local organizations was quite low: the only organization type to which a majority (76.2%) belonged was a church, and a plurality (37%) of the sample belonged to only one organization. The number of group memberships per person (and thus presumed social linkages in the community) was not significantly correlated with hazard ratings.

Connectedness was also tapped through several attitudinal variables. These were not highly intercorrelated except for "feel responsible for what happens to my community" and "feel capable of influencing decisions on local issues" (r=.33). Neither were they significantly correlated with most hazard ratings.

CONCLUSIONS

We have yet to compare the power of alternative hazard identification explanations directly. These conclusions are highly preliminary and subject to severe constraints--our analysis is still in its early stages (several of our measures of community connectedness and political views have not yet been analyzed, which may account for their generally poor showing), the difficulty of defining and measuring a concept (particularly problematic for "knowledge" and "experience"), the small and perhaps atypical sample, and the relatively narrow range of hazards examined. It is clear that the power of each model to explain hazard perceptions, though non-zero, is moderate at best (though correlations of .30 are typical for inter-attitude survey research) and some of the reported correlations appear counter-intuitive. Because considerable variance in benefit, risk, and acceptability assessments remains unexplained by these individual models, hazard perception model comparison must be a top priority for future research. Explanation may depend upon development of a composite model utilizing the complementary features of various approaches.

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SOURCES OF CORRELATION OF EXPERT OPINION -- A PILOT STUDY

J. M. Booker, M. A. Meyer, and H. F. Martz

Los Alamos National Laboratory
Los Alamos, New Mexico 87545

Expert estimates are relied upon as sources of data whenever experimental data is lacking such as in risk analyses and reliability assessments. Correlation between experts is a problem in the elicitation and use of subjective estimates. This pilot study seeks to identify the sources and structure of interexpert correlation and to discuss some of its ramifications. Until now, there has been no data that identify sources of correlation. Data were gathered using questioning techniques from ethnography and educational psychology. The results of this pilot study indicate that the key to correlation is in the way that people solve problems.

KEYWORDS: Subjective Judgment, Expert Opinion, Correlated Estimates, Problem Solving, Bootstrap

1. INTRODUCTION

This pilot study seeks to identify sources of correlation in expert estimates to provide useful information to managers and others who work with expert judgments. Identifying sources of correlation aids in solving problems associated with correlated estimates such as in aggregating multiple estimates and in obtaining the best coverage of the true value.

There has been much speculation about possible sources of correlation between estimates of experts but little evidence to identify a source. One speculation is that the theoretical orientations individuals learn during their education may be a source of correlated estimates. Other speculations are that the individuals' shared work experiences may lead to correlation. This research proposed and tested these common speculations as well as two additional ones: the process that the individual uses to solve the problem, and the length of time since the individual has worked on a similar problem. In addition, two factors were tested for their affect on the individual reaching the "correct" answer: the complexity of the problem, and the individual's problem-solving process.

The target population for the pilot was a group of 18 statisticians who were asked text-book statistical problems. The statisticians were questioned on their professional backgrounds and problem-solving processes using intensive interviewing techniques borrowed from ethnography and educational psychology. Data on human behavior can be expected to be fuzzy and, therefore, difficult to analyze.

The results indicate that a major source for the correlation among experts could be found in the processes they use to solve a problem. Experts using the same process, or path, tend to arrive at the same answer. No evidence was found to support the common speculations that there is some commonality in the experts' professional backgrounds (i.e., schooling or common work experience) to cause correlated estimates. The individuals' problem-solving paths included their assumptions about the nature of the problem and some algorithm or rule of thumb that required calculation. The paths that included simple and easy to remember algorithms most frequently led to the correct answer. Such paths are referred to as "straight pathways."

2. THEORETICAL BACKGROUND

Interexpert Correlation

Although expert opinion is commonly used as data, the question of sources of correlations between experts has not been studied (Dalkey 1975). Yet, there has been speculation as to the sources of correlation. For example, Baecher (1979) uses the term schools of thought to explain the correlation he found in the expert estimates on seismic hazards. He was able to group the experts into three schools according to their answers but could not explain this grouping because the experts had been anonymous.

Some authors seem to interpret correlation as a positive trait and others, as a negative one. Some view correlation as desirable, as an indication of consistency, reliability, and accuracy. They tend to eliminate outliers and value homogeneous expert populations (Comer et al. 1984). They may also find positive merit in not being able to link experts' estimates to their age, experience, or organization (Meyer 1982). Expert correlation is tacitly viewed as negative by those who place a high value on the diversity of opinions. For example, correlation could be viewed as evidence that the problem has not been considered from enough perspectives to obtain a quality answer (Seaver 1976); that the experts are making one major and probably highly conservative assumption (Ascher 1978); or that the experts are unconsciously following one person's view (Janis 1972). Outliers are not eliminated under this interpretation because diversity, rather than consistency, is valued.

A few authors have assumed that significant correlations exist and have investigated means for aggregating expert estimates. A primary reference on dependent estimation errors in a Bayesian context is Winkler (1981).

Factors Affecting Individual's Problem Solving

This paper does not place a positive or negative value on interexpert correlation but simply seeks to understand its causes. Because literature on causes of interexpert correlation was lacking, the authors reviewed literature on factors influencing individual's problem solving. This literature was used to postulate factors which could be sources of correlation (the subject's background, the recency of his exposure to the problem, and the algorithm he uses to solve the problem) and which could impact on the accuracy of the subject's estimates (the algorithm used and the complexity of the problem).

A previous study by the authors failed to indicate any correlation between an expert's solution and his age, position on the project, years of experience, job satisfaction, or professional degree (Meyer et al. 1981).

However, some other studies propose that traits which humans have in common may influence their problem solving. In particular, humans possess memory limitations (Hogarth 1980) that affect their reconstruction of events and their equations for solving problems. For this reason, the recency of the subject's experience in working a similar problem was postulated as a source of correlation.

A number of studies had shown that the problem itself has an effect on the answers given. For example, Tversky and Kahneman (1981) have shown that the presentation of the decision task influences the individual's response. In another study, the complexity of the questions seemed to have some impact on the answers (Comer et al. 1984). There seemed to be an increase in variance between answers for those questions that had been rated as more complex. These studies imply a link between the question itself and the answers that are selected.

Some studies have shown that the individual's problem-solving techniques influence his answer. For example, if individuals are instructed or assisted in breaking a problem into its component parts and in solving the parts, they give more accurate answers than do those who have not used this problem-solving technique (Hayes-Roth 1980; Armstrong 1975). The assumptions that individuals make are also likely to influence their answers. Ascher (1978) determined that one of the major sources of inaccuracy in forecasting future possibilities, such as markets for utilities, lay in the forecaster's failure to extrapolate sufficiently from present patterns.

Matz (1981) has approached the correlation between the individual's problem-solving path and answer by examining the errors made by the individual. She has proposed that problem-solving errors can be explained as a result of reasonable but unsuccessful attempts to adapt old knowledge to new situations. The present study elicited the subjects' algorithms for solving the problems because these studies indicated that the algorithms might be a source of correlation and estimate accuracy.

To elicit information on the subjects' algorithms, a technique from educational psychology was used in combination with one from ethnography. The educational psychology technique involves having the subjects think aloud.' The ethnographic technique is a means of intensively questioning individuals while minimizing the observer's bias. This technique is an iterative one whereby the subjects are repeatedly asked questions that are rephrasings of their previous answers.

This study's model of how people solve problems evolved from the above-mentioned literature and the subjects' responses. Individuals were viewed as selecting some algorithm to solve the problem based on their perception of the problem and what they thought they could remember. Their algorithms were procedures such as an equation or a set of operations that they intended to go through to reach a solution. Sometimes they remembered a simple algorithm or rule of thumb that could be applied to the problem. Other times, the subjects could only think of a more complex algorithm for solving the question. Often they would begin to execute this algorithm only to find that they could not recall it in its entirety. This population typically turned to visualization techniques to get an approximation of the information that they needed to solve the problem.

These algorithms plus any assumptions that the subjects made regarding the nature of the problem or the working of the algorithms were labeled "paths." These paths correlated to the answers given. For example, in question 2 on correlation, subjects' answers were clustered along four paths (Table I). Some assumed that the correlation was large and then used algorithms based on the relationship that sample size is small so the correlation does not have to be large to be significant (path 1). Others made no initial assumption and used no algorithm other than their attempt to visualize tables to determine where the correlation would be significant (path 2). Some assumed that the correlation was small and used algorithms based on the relationship that sample size is large so the correlation must be large (path 3). Some assumed that the correlation was small and used the same algorithms as described in the first path.

3. QUESTIONNAIRE DESIGN

Five classic, text-book statistical problems were asked. The subject areas of these problems were chi-square goodness of fit, Pearson sample correlation coefficient, random numbers, central limit theorem, and analysis of variance -- multiple comparisons tests. (The questions can be found in Booker and Meyer, 1985).

TABLE I

CLUSTERING OF ANSWERS BY PATHWAY FOR QUESTION 2

	("Straight") Path 1	Path 2	Path 3	Path 4
Assumptions That the correlation is...	large	not considered	small	small
Algorithms As the sample increases, the correlation...	does not have to be large	is not considered	has to be large	does not have to be large
Answers	4 8 8 8 9	12 15 15 17 18	5 5	20 23 25 27 27 39

Two types of questions were asked to identify sources of correlation: (1) those on the experts' professional training and experience, and (2) those on how they solved the problem. The first type included questions on the subject's background such as where he went to school, where he worked, and for how long. The background questions were to provide information for matching individuals by school or work experience should education or common experience prove to be sources of correlation. To further investigate work experience as a source of correlation, three populations of the statistics group were interviewed: current members, new members, and ex-members who maintained contact.

The second type of questions were asked because of the literature on problem solving and the authors' previous experience (Meyer et al. 1981; Meyer et al. 1982). Each subject was asked to think aloud while solving the problems. To obtain the necessary information, the subject was frequently queried about his thoughts, using an ethnographic technique. The question information that the subject used in solving the problem (cues), his assumptions, and algorithms were all recorded in detail.

In addition, the subjects were asked when and where (school or work) they had last worked on a similar problem. The duration of each interview was also recorded. It was thought that the amount of time spent might relate to problem-solving style or accuracy because the more time consuming methods of problem solving have this effect (Hayes-Roth 1980). The average interview lasted 59 minutes with a standard deviation of 14.

4. ANALYSIS OF RESULTS

Sources of Interexpert Correlation

It is always difficult to reduce highly qualitative data, and this task was compounded by not knowing, in advance, which factors were sources of correlation. For this reason, factor analysis was first used to investigate the structure of the independent variables (the subjects' problem-solving paths and professional backgrounds). Many of these variables were correlated to each other, which means that they reflected similar information. The background variables (14) were trimmed using the factor loadings from a factor analysis and principles from judgment theory. The resulting set of independent variables included variables characterizing the number of years in the Statistics Group at Los Alamos National Laboratory, the number of years of statistical training, the percentage of current work involved in "text-book" types of problems, whether the respondent's degrees were in statistics, and whether the respondent was currently a member of the Statistics Group at Los Alamos.

General linear models and categorical analysis were used to investigate the relationships between the pathways and background information and the answers. The sole purpose of these analytic procedures was to produce a set of variables that highly correlated to the answers. This set would then be considered as a source of correlation.

The results of the linear models on the final set of independent variables quickly indicated that many of the pathway characteristic variables provided good sources of correlation to the answers (Table II). These pathway variables accounted for a large percentage of the total best model's variation. In question 1, the pathway variables accounted for 48% of the 78% variation, in question 2, for 60% of 68%, in question 3 (part A), for 38% of 38%, in question 4, for 73% of 78%, and in question 5, for 60% of 68%. By contrast, the background factors, the duration of the interview and the recency of experience, were not suitable for predicting the answer. At best only a few variables such as the percentage of the subject's current work on text-book problems, were ever significant and then only for one of the total questions (at a 95% level of significance).

In examining the results of the linear models, a new hypothesis was tested to attempt an explanation of why subjects chose certain pathways. The hypothesis was that aspects of subjects' profession backgrounds led them to select particular paths, and thus indirectly determined the answers. However, no supportive evidence for this hypothesis was found.

Accuracy Study

Many studies have investigated the accuracy of experts' estimates in both real and experimental situations. For example, a recent study by Martz et al. (1985) confirmed that people are unable, in experimental situations, to give accurate percentile estimates. Although the goal of the current study was not one of testing subjects' ability to give correct answers, that aspect was explored because of the strong connections between pathways and answers.

Table II

SUMMARY OF PILOT STUDY RESULTS

Variables	Emerges as a Source of Correlation*	Correlates to Accuracy
Subjects' pathways (Assumptions) (Algorithms)	6 out of 6** questions	6 out of 6 "straight" pathways
Subjects' Education		
Degree in Stat.	None	None
Work Experience		
Stat. group member	None	None
Years in Stat. group	None	None
Percentage of current work on text-book problems	1 out of 6 questions	1 out of 6 questions
Recency of Experience	1 out of 6 questions	None
Duration of Interview	1 out of 6 questions	1 out of 6 questions
Question Complexity	Not testable	6 out of 6 questions
Years in Statistics	None	1 out of 6 questions

*Significant at a 5% level (i.e., with at least a 95% chance of being a source)
**Five basic questions were asked but question 3 had two distinct parts.

More correct answers were given on questions that had been rated as simple. The questions were rated on five characteristics to gauge their simplicity: 1) familiarity of formulation, 2) availability of algorithms, 3) need for assumptions, 4) number of acceptable answers, and 5) post survey variation.

Each of the questions was rated on these five characteristics, and these ratings were summed. The more complex the question, the higher the sum. A general linear model, using the per cent of correct answers as the dependent variable and the sum of the number of complex features as the independent variable, showed that more correct answers were indeed given for the simpler questions.

Aggregation of Expert Estimates

In using expert opinion data, the analyst needs a way of combining all the expert information into a single estimate representing a central measure (e.g., mean or median) with an estimate of the dispersion or range of the values (e.g., a variance or confidence interval). Previous studies (see Martz et al. 1985) have used many elaborate estimators to combine the individual estimates. The results presented here suggest that one way of combining the expert estimates is to use the information on the solution pathways because this correlates to the answers.

If pathways correlate to particular answers, which pathways predict the acceptable answer? In all questions, the pathways that led to the acceptable answers were the paths where subjects used simple, easy to remember, rules of thumb that, when applied to the problem, produced answers that did not conflict with their intuition. These pathways were labeled "straight" pathways. The "straight" paths can be identified without knowledge of the acceptable answers. The answers from the experts following the "straight" pathways can be used to formulate central measure estimators that can better predict the acceptable answers. If the medians from "straight" pathways are used as the aggregation estimator, the correct or acceptable answer is covered in all five of the questions. If, instead, the medians from all the data are used, the correct answer is only covered in two of the five questions.

For questions 2 and 4, bootstrap sampling can be used to illustrate the coverage of the correct answers by medians because these answers are in the form of continuous variables. Bootstrap simulation and sampling procedures provide methods of obtaining confidence intervals and variance measures when the distribution of the data is unknown (Efron 1979). These methods are most helpful for small samples and for data that is fuzzy (containing uncertainties). Bootstrap distributions for the mean, median, and geometric mean for questions 2 and 4 were formed using (1) all the data, and (2) the data from subjects using the "straight" pathways. Fig. 1 illustrates the resulting distributions of the medians of question 2.

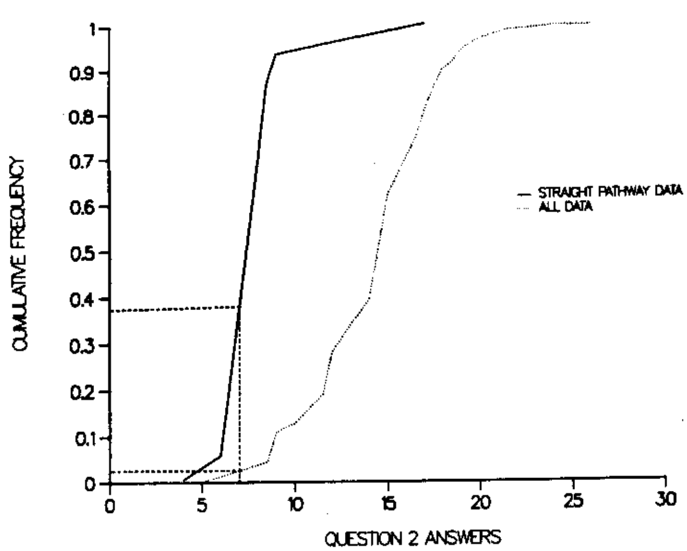

Figure 1
Bootstrap Medians For Question 2

The empirical cumulative distribution plotted in Fig. 1 represents the medians for all the data (solid curve) and for the "straight" pathway data (dashed curve). The correct answer is marked for each curve by the dashed line intercepting the appropriate percentile of the distribution. The all-data median does not cover the correct answer even with an interval covering 95% of the distribution. However, the correct answer is covered with a 95% interval when the "straight" pathway data is used.

5. CONCLUSIONS AND RECOMMENDATIONS

Experts' estimates were found to correlate to the experts' problem-solving techniques and not to any features of their professional backgrounds. The paths that experts used to reach solutions included algorithms and assumptions. Assumptions and algorithms were found to correlate to the answers because they are integral parts of the path. In addition, paths were found to relate to the accuracy of the answers. "Straight" paths, and therefore the assumptions and algorithms which composed them, led to the acceptable answers.

From these conclusions, a few recommendations can be offered in eliciting expert opinion:

1. The experts should be provided with the correct algorithm, if one is available, and with any assumptions that they should make. If these components of problem solving are provided, the experts are less likely to make errors resulting from incorrectly remembering the algorithm, trying to apply an inappropriate algorithm, or making an unacceptable assumption.
2. The experts should be requested to explain their thinking, in detail, and this information should be recorded. There are two advantages to having a record of the experts' thoughts. First it can be used to explore sources of correlation or to select the answers from the pathways that shows the fewest obvious errors. Secondly, it allows the expert's understanding to be monitored.

The next step of this research will be to verify the above-mentioned results and to examine why experts select particular pathways to solution.

ACKNOWLEDGEMENTS

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WHY GOOD RISK ANALYSTS HAVE TROUBLE WITH PUBLIC COMMUNICATIONS-

A QUANTITATIVE ANALYSIS

Raymond Johnson* and W. Larry Petcovic**

Communication Sciences Institute*

Advanced Communication Techniques**

ABSTRACT

Effective risk management requires effective communications. the communication strengths and limitatiols of over 300 health risk analysts, in the radiation protection profession, have been analyzed by the Myers-Briggs Type Indicator. This indicator measures the magnitude of our preferences for gathering data by SENSING(S) or INTUITION(N), for making decisions by THINKING(T) or FEELING(F), for how we relate to others by JUDGING(J) or PERCEIVING(P), and for how we get our energy by EXTRAVERSION(E) or INTROVERSION(I). Profiles for these risk analysts show a strong preference to INTJ. They tend to be self confident, decision makers, practical, orderly, logical, outstanding in research and as executives, hard workers, high achievers, organizers, and pragmatic strategists. On the other hand, they can also be very independent anc single minded. They may ignore the views of others and may appear unemotional, cold, demanding, critical, reserved, and determined. They may neglect social rituals and may not like to waste time in idle dialogue or play. This paper will analyze how an awareness of Myers-Briggs Type can be used to develop effective approachs to communication and risk management.

KEY WORDS: public communications, communication style, Myers-Briggs Type Indicator (MBTI), radiation, radiation protection, risk management, and risk analysts.

INTRODUCTION

Since the beginning of the nuclear age, the radiation protection profession has experienced difficulties in communicating about radiation issues. During emergencies these communication problems are compounded as an anxious public seeks assurance of their safety. At such times, most radiation protection professionals would rather avoid communications that may involve confronting other peoples' anxieties, especially when they perceive the public's fears as technically unfounded and irrational. Unfortunately, while our ability improves for estimating potential health risks from radiation, our ability to communicate what we know is not keeping up with the technology.

What we have tried over the years to improve our communications has largely been a matter of simplifying and clarifying radiation concepts and using analogies with other sources of health risks. This approach is mainly a one way communication of information from radiation experts to hopefully achieve understanding by the public. While this transfer of technical data is necessary and helpful, and may result in some level of technical understanding, it is not a sufficient basis for public decisions. The public also makes decisions on the basis of feelings and perceptions of health risks that go beyond technical understanding.

This is about the point where most radiation prodessionals back away, except for a few who seem to have a natural talent for communication (often honed by hard trial and error experience) and a few who are still striving to develop more effective approaches. Several health physicists in the latter category, form the Baltimore-Washington Chapter of the Health Physics Society, began a study in 1983 of communication needs in radiation protection. This study originated as a project of the Public Information Committee, chaired by the first author, and is still ongoing as a project of the Communication Sciences Institute. Out of this study have come a series of three day workshops to provide radiation professionals with practical communication skills to meet their needs. These workshops are now built around a concept of communications called the Johnson - Petcovic Synchronized Communication Model. This paper will consider the first two elements of this Model; namely understanding ourselves and understanding our audience, as a source of insight into why radiation professionals have trouble communicating especially during emergencies.

Myers-Briggs Type Indicator

A powerful tool for understanding ourselves and our communication style is the Myers-Briggs Type Indicator (MBTI). This is a 166 question, multiple-choice, test based on concepts defined in the 1920's by a Swiss psychologist, Carl Jung (Ju23). The MBTI was developed in the 1940's as a practical means of measuring Jung's concepts of psychological type by two Americans, Isabel Myers and her mother, Katharine (My62). The MBTI is now a widely used instrument for management and organizational development, team building, and communication training (My80).

The MBTI measures the strength of our natural preferences in four areas:
1) Where we get our energy - by EXTRAVERSION (E), from interacting with people, activities, and things; or by INTROVERSION (I), from inner reflection, ideas, and private time.

2) How we gather information - by SENSING (S), using our 5 senses for specific, detailed, factual, concrete data; or by INTUITION (N), seeing patterns, relations, possibilities, and the big picture.

3) How we make decisions - by THINKING (T), using logical analysis, laws, consistency, and objective criteria for what is true; or by FEELING (F), using personal values, other's concerns, harmony, compassion, and sentiments for what is good.

4) How we relate to the world - by JUDGING (J), striving for conclusions, planning, and scheduling to reach closure; or by PERCEIVING (P), enlarging

our awareness, keeping options open, being spontaneous, open ended, and resisting closure.

Since January 1985, the first author has administered the test to 307 professionals in radiation protection; including health physicists, scientists, nuclear engineers, lawyers, physicians, educators, managers, technicians, and public information specialists involved in communicating with the public, radiation workers, and coworkers about radiation issues.

The measured preferences of this group are as follows:

	PERCENT PREFERENCE	
Category	Rad. Prof.	Public
E	37	75
I	63	25
S	42	75
N	58	25
T	77	50
F	23	50
J	66	50
P	34	50

These results show that the overall preference of radiation professionals is for I, N, T, and J. This particular combination of preferences is one of 16 possible combinations of Myers-Briggs Type and represents only one percent of the average population. The INTJ preference is typical for scientists. As INTROVERTS, they are not people oriented and are less likely than EXTRAVERTS to be communicators. As INTUITIVES, they are comfortable in the world of abstract concepts and theories. As THINKERS, they prefer to make decisions on the basis of logical, rational, analysis, and as JUDGING types they prefer to lead systematic, orderly lives, and make schedules and plans to reach closure on all issues.

INTJ's tend to be self confident, independent, pragmatic, loyal to their organizations, skeptical, critical, determined, single-minded, and stubborn. They are original thinkers, builders of systems, appliers of theoretical models, and natural brainstormers open to new concepts. They are strategists with a concern for consequences, efficiency, and completion. They are organizers, hard workers, and high achievers, who are stimulated by difficulties. They look for coherence and consistency, are capable of great drive, and they are outstanding in research and as executives.

The distribution of preferences for the radiation protection profession is shown as percentages in the following Myers-Briggs Type Table. The numbers in the left corner of each block are percentages for the average population. This table is based upon 307 MBTI profiles, including 55 women.

Myers-Briggs type Table - %

ISTJ 21 6	ISFJ 2 6	INFJ 4 1	INTJ 17 1
ISTP 5 6	ISFP 2 6	INFP 5 1	INTP 7 1
ESTP 1 13	ESFP 1 13	ENFP 5 5	ENTP 8 5
ESTJ 9 13	ESFJ 1 13	ENFJ 3 5	ENTJ 9 5

This Table shows that 6 types (ISTJ, INTJ, INTP, ENTP, ESTJ, and ENTJ) make up 71 percent of the radiation protection profession. In contrast,}5 other categories that make up 51 percent of the public (ISFJ, ISFP, ESTP, ESFP, and ESFJ) include only 7 percent of the radiation profession. These data show that professionals in radiation protection tend to have preferences that are quite different from the average population. These preferences are the basis for each person's choice of profession (or job function) and also are the source of difficulties in communication, particularly with those whose preferences are different. Without an MBTI understanding of differences in attitudes, beliefs, values, data gathering, and decision making, our preferences tend to be seen as wrong by persons with opposite preferences. Such perceptions of wrongness are the reason for most conflicts and breakdowns in communication on our jobs and in our homes.

Concern for such perceptions was the basis for Isabel Myers' 50 - year effort to develop and apply the MBTI. In 1980 she published "Gifts Differing" (MY80) to show how our natural preferences represent gifts and strengths that may be used to complement the gifts and strengths of others. She wanted us to appreciate our special gifts and those of others as a source of understanding to reduce friction and to improve communication among all types of people. (See the Health Physics Society Newsletter for a discussion of the special gifts of radiation professionals (Jo85a)).

Temperament Types

Another way to appreciate the uniqueness of radiation professionals is to look at the four 2-letter combinations of preferences called TEMPERAMENTS (Ke78). Our temperament is determined by our special combination of preferences that dominate or modify everything we do in ways that are as recognizably ours as our signature. Our temperament is that inner motivation that guides our lives to repetitively seek a uniform style of living that we must satisfy regularly in the same way that we have to satisfy hunger. The table below shows the four temperament groups.

	PERCENTAGES	
TEMPERAMENTS	Rad. Prof.	Public
NT	41	12
SJ	33	38
NF	17	12
SP	9	38

The primary temperament for the radiation profession is NT (41%) which represents only 12 percent of the average population. The quest for NTs is for competence, and their style is visionary. They are powerful conceptualizers and responsive to new ideas. They hunger for knowledge and are challenged by riddles. They want to understand concepts and may learn by arguing. They are authority counterdependent, i.e. they push against the rules and authority. Their Achilles' heel is incompetency - they cannot stand incompetency in others (or themselves). To NTs everything needs testing for competency and NTs determine the criteria. They tend to be critical of others and themselves about "not measuring up." NTs also tend to be game players and can miss what is immediately important. They like the complex and theoretical and may not be inclined to give simple answers. They can appear impersonal and aloof and may not express appreciation. They like to start more than to finish projects. (See Jo85b for more details on the other temperaments).

NTs may have difficult in communicating with other temperaments (88 percent of the public) when they think of them as incompetent, overly sensitive, illogical, to structured, or unthinking. NTs especially tend to argue with SJs. They can be impatient with others whose future vision, imagination, or grasp of complex subjects is less than theirs.

Preferred Style

Everyone has a primary communication style that they prefer to use. The preferred style will either be based upon one of the functions for gathering data (SENSING or INTUITION) or upon one of the functions for decision making (THINKING or FEELING). Because we repeatedly use our favorite function in communication, that function will likely be much better developed than the other three functions. Therefore, we will be most skillful and most comfortable using our preferred style and this style will be the "wavelength" for our best communication. Two people will communicate with the greatest probability of success when they are both on the same "wavelength."

The communication problems that most of us face can be attributed to relying solely upon our preferred style even when it is different from that of the person with whom we wish to communicate. Since most people do not know of their own style or that of others, they naturally go with their own primary preference and hope for the best. However, the chances are small that any two people at random will have the same primary communication style, as we will see below.

The MBTI provides a quantitative measure of our preferred first, second, third, and fourth approaches for communicating with others as shown in the following table.

COMMUNICATION STYLE PREFERENCES

% Rad. Prof. / % Public

	1st	2nd	3rd	4th
T	56 / 25	21 / 25	12 / 15	11 / 25
N	25 / 12	33 / 12	17 / 38	25 / 38
F	10 / 25	13 / 25	47 / 25	30 / 25
S	9 / 38	33 / 38	24 / 12	34 / 12

The preferred communication style of the radiation protection profession (56 percent) is the logical, rational, analytical THINKING approach. This approach is not the first preference for 75 percent of the public. If the radiation experts turn to their next highest preference for primary style (25 percent for INTUITION), that approach will miss 88 percent of the public who prefer not to communicate on that "wavelength." Most of the public prefer SENSING (76 percent) as their first and second approach to communication. This approach is the first preference for only 9 percent of the radiation profession. (For more details on how to determine your primary style see Johnson (Jo85c) and Yeakley (Ye82).

Least Preferred Style

While it may be helpful to know that our communication strengths come from our primary style, it is also helpful to realize that our greatest weakness involves our fourth or least preferred communication style. Our least preferred style uses our least developed and least controlled function. For the radiation protection profession, FEELING and SENSING are the least preferred functions (see the style chart above). For these people, these two functions will often be expressed in ways that are immature, infantile, unadapted, and "inferior" according to von Franz (vo71).

Our communication problems arise when someone attempts to communicate with us on our least preferred wavelength. This may very well happen during radiation emergencies when someone approaches us on a FEELING or emotional basis seeking sensory (SENSING) data to relieve their anxieties. They are then asking us to function in our most uncomfortable domain. Our inferior functions are also slow. For example, if you ask a THINKING type what they are feeling, they will usually have no idea and may take a long time to get in touch with their feelings or any one elses. In contrast, the primary THINKING style comes spontaneously and is immediately available for response.

We will feel threatened and vulnerable when someone addresses our "inferior" function. We will become touchy and defensive in that area. For example, INTUITIVES may find themselves exasperated when their health risk assessments are challenged by SENSING demands for more concrete, factual, tangible, and detailed data, especially when the data are scarce or uncertain. In such cases, the INTUITIVE wants to say, "Take my word, I am the expert, believe me." But, that is not enough for SENSING types and the INTUITIVES find their credibility and competence in question.

The inferior function also comes out unbidden during crises or times of stress and may inject any number of dark possibilities. For example, a normally down-to-earth, realistic, SENSING type may suddenly start worrying about all kinds of imagined consequences of radiation exposures. This is typical of negative inferior INTUITION. The SENSING type's perception of health risks than becomes clouded by the invasion of the inferior INTUITION's fearful visions. Persecution ideas creep in and he begins to get sinister premonitions of illnesses or other misfortunes that may befall him.

Primary INTUITIVES will also have trouble in areas involving their inferior SENSING function. For example, INTUITIVES may exceed their reasonable limits both psychically and physically because they are not tuned in to the needs of their body. They are also inclined to suffer great vagueness where facts are concerned. INTUITIVES are prone to pass over an amazing number of facts and just not take them in. And then, when suddenly confronted by facts in an emergency, they may make completely erroneous deductions.

The primary THINKING types tend to spend their whole lives settling problems, organizing projects, and stating things in clear logic, and only late in life do they ask themselves what they have lived for and then get in touch with their inferior FEELING function. The unconscious and undeveloped FEELING of these types may also come out under stress in barbaric or fanatic outbursts that overwhelm the person. All sudden conversions have this quality (vo71). The inferior FEELING makes black and white judgments, love or hate, is easily misled by others, and makes judgments on values rather than facts.

Primary FEELING types will dislike having to use their inferior THINKING function, especially if asked to think about philosophical principles or abstract concepts. Because THINKING is neglected, it tends to come out as primitive thinking judgments with cynical negative qualities. In a crisis, a normally friendly FEELING type can suddenly become a block of ice. Dark thoughts of illness, death, and tragedy spring to mind like a momentary cold draft. Little wonder that such types may want to avoid taking time to think, and may adopt other people's THINKING judgments without checking out the basis for themselves. Their inferior THINKING is easily overwhelmed with too much detail or too many facts. So they latch on to one or two thoughts and race ahead imposing these thoughts on the facts.

People are easily influenced in the area of their inferior functions and are prone to make mistakes in these areas. In contrast to their primary function where they feel strong, broadminded, and flexible, in their inferior area they get fanatical and touchy, and tend to make sudden emotional responses, particularly when under stress, without knowing why. Propaganda can make use of the people's ordinary suspicions against others arising out of the inferior function. Thus, primary SENSING-FEELING types may be easily influenced to doubt the intuitive intellectual types representing government bureaucracy or private industry during emergencies. Radiation experts using their primary INTUITIVE-THINKING style may be readily perceived as insensitive and trying to cover up the facts.

Those who oppose nuclear technology know the value of emotional appeals to the inferior function. They know better than to argue with radiation professionals in their INTUITIVE-THINKING domains where they are strongest. Instead, they argue in the SENSING-FEELING domains where these professionals tend to be weakest. This is primarily why radiation professionals are so continuously frustrated by the antinuclear movement (and probably vice versus).

To be Effective

To improve your odds for successful communication about health risks, you will do best to use the preferred communication style of your audience. You may have to adjust your own style for this purpose. If your listener prefers INTUITION, then talk with them in terms of patterns, the "big picture," connections, future possibilities, imagination, innovation, creativity, hunches, various implications, and meanings. If they prefer FEELING, then talk in terms of personal values, people, sentiments, motives, caring, harmony, affirmation, appreciation, compassion, trusting, and conclusions about what is good. When your listener prefers SENSING, talk in terms of specifics available to the five senses, practical/factual details, the present moment, what is realistic, measurable, grounded, literal, and what makes sense. If you are talking with a THINKING type, then use your best logical, rational, analytical approach to present an objective, impersonal argument based on law and evidence to draw conclusions on what is true.

If you do not know you MBTI type or that of the other person, then review the characteristics of each style preference above for clues. When you have no data on your audience, remember that 75 percent of the public are SENSING types. So the SENSING approach may be a good one to start with. If they are in a people oriented job, then try a FEELING approach first. if they are in the radiation protection field, then use your THINKING style first. Most people will give you clues on how they "think" or "feel" so you can adjust accordingly. In any case, be prepared to shift gears if your first approach is not working. Keep in mind that although our INTUITION and THINKING preferences are most important for doing well in our jobs for determining radiation health risks, these preferences may not be our best approach for communicating what we know about health risks to the general public.

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TIME BUDGET ANALYSIS AND RISK MANAGEMENT: ESTIMATING THE PROBABILITIES OF THE EVENT SCHEDULES OF AMERICAN ADULTS[1]

Norman P. Hummon, Linda Mauro and George O. Rogers

Department of Sociology and University Center for Social and Urban Research
University of Pittsburgh

ABSTRACT

Comprehensive risk management must account both for the exposure and consequences of risks. Time budget analysis focuses on the activities and location of people, which are directly related to potential exposure, and consequences of risk. The analysis of the distribution of daily activities allows risk analysts to adjust exposure likelihoods for the changing population distribution over the course of a 24 hour period. In addition, time budget analysis allows the risk analyst to account for shifts in potential consequences associated with location of people at various times of the day. This paper examines three significant aspects of time budget analysis and risk management. First, the direct exposure rates to ongoing hazards as a function of the amount of time spent at risk (e.g. in an automobile, or airplane, or outdoors in a neighborhood adjacent to an uncontrolled hazardous materials site). Second, the effect on the likelihood of exposure to and severity of consequences for relatively sudden events (e.g. toxic chemical spills, radioactive leaks, other airborne risks transmitted via the plume-exposure pathway, tornadoes, earthquakes and flash floods). Finally, the effect on risk management through effective emergency management is directly related to location and activity of people at various times of the day (e.g. likelihood of warning receipt, probable evacuation flow dynamics, and likelihood of inadvertent adaptive location).

KEY WORDS: Time Budget, Risk Management, Exposure, Consequences, Emergency Management

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INTRODUCTION

Risk management is concerned with the problem of describing the relation between a risk generating phenomenon and a human population. The characterization of this relation is particularly useful when it accounts for both space and time. Examples of temporally and spacially distributed hazards abound: Dangerous weather systems impact specific geographic locations during particular seasons of the year and times of the day. Nuclear power plants reside at specific locations, and power lines follow identifiable routes. This relation between a risk generating phenomenon and a human population can be conceptualized as several stochastic processes (Rowe 1977, Lowrance 1976, Shrader-Frechette 1985). One is concerned with the likelihood of a risk generating event, (eg. the likelihood of a tree falling in the forest). Another concerns whether, given such an event, it would impact the human population (eg. given that a tree falls, the likelihood that it would hit someone). And finally given the event and the impact, what is the distribution of consequences. This paper concerns the second set of probabilities and their estimation.

The approach used to estimate these probabilities is based on a simple idea; probabilities can be estimated from data on how and where people spend their time. For example, the probability of whether a person will be at home at 6:15 PM can be estimated from the time and activity logs that comprise the foundation of time use research. In fact, time budget analysis allows the risk analyst to describe the activity profile for the entire day in terms of the best point and interval probability estimates for an incredibly detailed range of activities. This paper highlights the use of time budget data in risk management.

Three Types of Uses are Highlighted:

1. Estimating direct exposure and dose rates due to ongoing hazards (eg. being outdoors in neighborhood adjacent to an uncontrolled hazardous materials site, being indoors subjected to "indoor pollution," or outdoors exposed to ultraviolet rays of the sun with its possibility of skin cancer).

2. Estimating exposure, dose and potential severity of relatively sudden hazardous events (eg. being located in an area subjected to a toxic chemical spill, being indoors when an earthquake or tornado occurs, being outdoors during a radiation leak at a nearby facility).

3. Estimating the likelihood of effective emergency management in terms of emergency planning and the dissemination of warning, potential for (other inadvertent) adaptive/maladaptive locations, and potential for adaptive response.

Time Budget Surveys

In 1975, the Survey Research Center at the University of Michigan administered a time budget survey to a national probability sample of U.S. households (Robinson 1977). The same households participated in a second panel of the same survey in 1981 (Juster et al, 1983). In the 1975 survey, 1519 households were surveyed, which included 1519 respondents and 887 spouses. In 1981, attrition in the panel reduced the sample sizes to 620 households, with 620 respondents, and 376 spouses. The 1981 survey added the time budgets of children in the households.

A comparison of 1975 with 1981 results indicates that the attrition in sample sizes caused little, if any, bias in the results. Controlling for demographic variables indicates that the time budgets of U.S. households were amazingly stable over this period of time. The results in this study are from an analysis of the 1981 panel data.

For both the 1975 and 1981 surveys, four waves were administered, one during each season of the year. For each wave, respondents and spouses were asked to construct a one day (24 hour) log of his or her activities. The log describes the set of all activities the person engaged in during the previous day. Over the four waves of each survey, respondents reported on their activities for two weekdays, and two week end days. The 1975 survey contains 7207 person-days of data and the 1981 contains 3350 adult-days and 881 children-days.

Most of the published reports of these University of Michigan data are based on an aggregated "synthetic week" (Stafford and Duncan 1978 and 1980, Stafford 1980). The two weekdays and two weekend days are combined and weighted to estimate how Americans spend time over an annual average week. For many types of studies, such data are well suited. However, for risk analysis, the synthetic week approach does not provide enough detail about the daily schedules of people. Therefore, this analysis developed a different data structure better suited to risk analysis.

<u>The Period-Activity Data Structure</u>

The raw time log records contain, in part, the following items: respondent identification number, day of week, month, date of interview, activity code (ie., a typology of 233 detailed activities), time activity began, time activity ended, secondary activity code, and elapsed time for activity. Typically, about 30 records describe the activities for a respondent for each day. These raw data are processed in two ways to form a period-activity data structure.

The Michigan time budget activity codes cover 233 detailed activity types. The detail is illustrated in terms of a few examples. Activities in the home, such as meal preparation, are coded in terms of several categories, including meal preparation -- cooking, meal preparation -- clean-up, and meal preparation -- other. Travel activities are comprised of travel to and from work, in search of employment, to and from shopping and to and from day care facilities, to name but a few. Both primary activities, those dominating a particular period, and secondary activity, those being conducted in the background while other activities are undoubtedly conducted, use these detailed activity codes.[2] To use these time budget data in risk management, these detailed data are collapsed from 233 activity codes to 11 broader categories reflecting some major risk management situations. Specific risk applications are best treated in terms of their unique exposure-dose-consequence profiles and their associated time budget implications. The collapsed activity codes are: 1) at home--asleep, 2) at home--active, 3) at work, 4) watching TV, 5) listening to the radio, 6) at neighbor's home, 7) not home--indoors, 8) shopping for goods and services, 9) at home--outdoors, 10) not at home--outdoors, 11) in transit.

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2. A secondary activity is one that is engaged in at the same time as a primary activity. An example is listening to the radio (secondary) while eating dinner (primary).

These eleven categories[3] describe the kinds of places where people conduct their daily activities. They maintain the distinction of being home or away from home, being indoors or outdoors, and being active or asleep. Also, these broader categories of the daily activities are a mutually exclusive and exhaustive re-categorization of the 233 detailed codes. Interest concerning specific risks may not entail exhaustive categories, but for our purposes this seems most appropriate. Finally, because sleep time is both such a dominant activity in a person's time budget, and because it is a primary consideration risk management, it is maintained as a separate activity.

The second part of the raw record processing involves aggregating time spent in individual activities into composite activity time in the 11 categories during a period of the 24 hour day. Twelve two hour periods were used for this aggregation. Thus for each respondent in each wave, a data record was computed that described the number of minutes spent in the 11 category codes during each of 12 periods of the day. This means period-activity record contains 132 time use variables, plus other variables describing the day, the respondent, and household characteristics.

Analysis of the Period Activity Data

The most dominant feature of the average annual time budget is being at home asleep. Comprising 34.8 percent of an individual's total daily time on average, being home asleep is heavily concentrated in the midnight to 6am period, secondarily in the 6am to 8am and 10pm to 12 midnight periods. For the five two-hour periods beginning at 10pm, the average amount of time spent sleeping at home in each two-hour period is 50.3, 88.1, 94.4, 90.8 and 52.7 percent respectively. This seems to reflect a daily pattern of the typical household. In fact it is what one might expect, but the implication for risk management rests in the amount and sequence of the sleep activity.

The second most dominant feature of the annual time use budget is the time being active in the home. This primary activity comprises 23.9 percent of the typical day. Together, in-home active and asleep categories account for 58.8 percent of the total daily activity of adult Americans. The third most dominant daily activity is work. Working comprises another 11.1 percent of the average total time budget. Concentrated during daylight hours (ie. 8am to 5pm), at its peak periods work comprises 25.8 percent of the period between 10am and 12 noon. Taken jointly these three primary activities comprise 69.9 percent of an average person's daily routine. Figure ' presents the annual average time use budget for all eleven primary activities.

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3. For some analyses, codes 6, 7, and 8 were combined into a more general not home, indoors, category.

While the remaining categories, taken jointly comprise 30.1 percent of the total time budget, separately none of the remaining categories account for more than 10 percent of a typical person's total time. Watching television accounts for the majority of the remaining time, at 8.1 percent. Compressed primarily within the 8pm to 10pm period, and secondarily within the two-hour period before and after prime-time viewing, watching TV is the forth most dominant daily activity. Considering almost all TV viewing is conducted in the home, all activities in the home comprise 66.9 percent of the daily budget. Adding the amount of activity conducted outdoors at home and in neighbor's home, 72.7 percent of the daily activity takes place in the residential neighborhood. This underscores the use of residential population data as the foundation for risk management issues concerning exposure, severity, consequences, and emergency mitigation. However, the more detailed time budget analysis builds more precise daily location/activity into the exposure/consequence quantification.

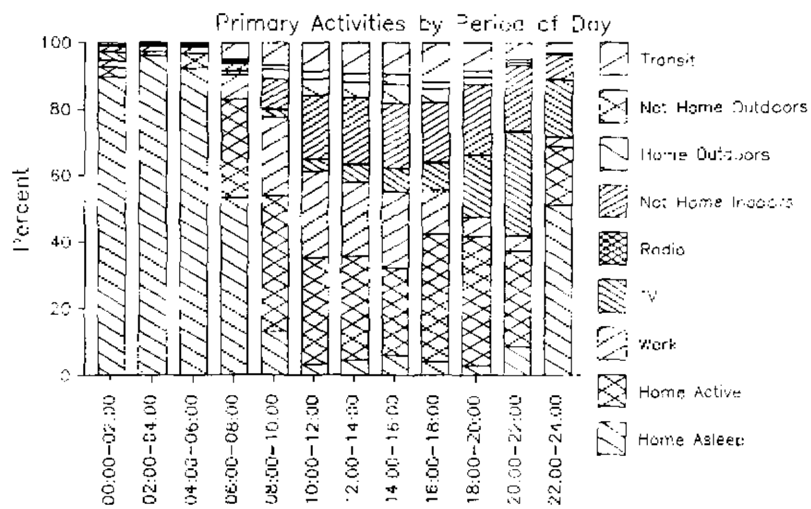

Figure 1

Annual Average Time Use Budget

Electronic media, including radio and television exposure, account for slightly more of the daily activity, however, when secondary media exposure is considered. The media "window" expands from 8.3 to 12.7 percent of the average daily time. This analysis suggests that nearly 13.0 percent of the average daily activity is exposed, either through primary or secondary activity to the electronic media of TV or radio. Figure 2 highlights the media exposure window which is critical in connection with emergency warning--alerting and notification. As a primary activity, radio provides very little warning potential, the maximum exposure as a primary activity is during the 6am to 8am period, and is only 0.3 percent. As a secondary activity, radio provides about a 4 percent exposure across the working hours of the day, with a peak of 4.8 percent in the 8 a.m. to 10 a.m. period. Radio listing falls off in the evening, when television, as a primary activity predominates. TV offers an 8.1 percent coverage as a primary activity, which increases to 10 percent when taken as a primary and secondary activity. During Day-light hours (ie. 8 a.m. to 6 p.m.) TV accounts for 2.4 percent of the primary activity. However, it provides 5.9 percent coverage during the same period as a primary and secondary activity.

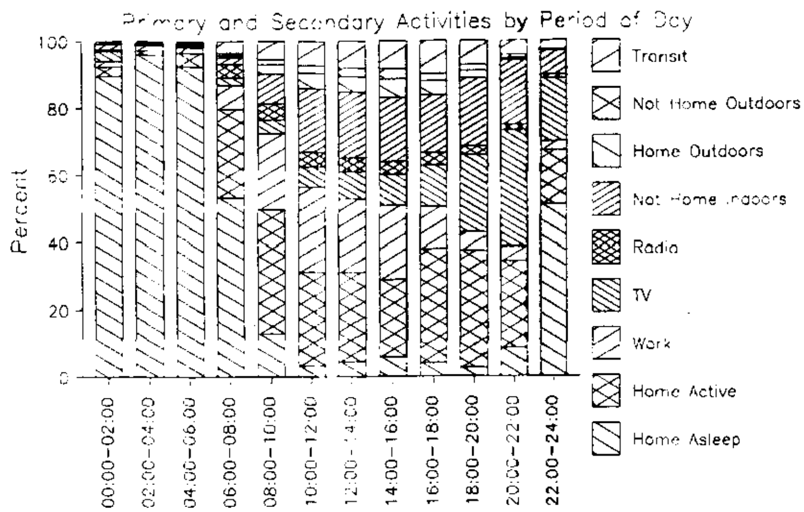

Figure 2

Annual Average Time Use Budget

Activity conducted away from home indoors accounts for 11.4 percent of the typical day. This activity is comprised of 3.7 percent in neighbor's home, 3.5 percent shopping and 4.2 percent in other indoor locations away from home. While shopping seems to be concentrated in the early afternoon periods, other indoor activities away from home seem to increase through the day-light hours, tapering off after 10pm.

Transportation activities comprise 5.6 percent of the average individual's day. Being in transit is concentrated in the day-light hours, steadily increasing from 6am, and reaching its maximum during the evening rush hour. Furthermore 15.4 percent of the time in transit is exposed to the electronic media, presumably the radio.

Low-level Ongoing Hazards

The use of time in specific places, within specific areas, undertaking particular activities is directly related to exposure to ongoing hazards. Because the average adult American spends so much time at home, the exposure within the home is fundamentally important. The World Health Organization task force suggested guidelines to control only a handful of the more common indoor pollutants. The suggested standards covered, formaldehyde, asbestos, carbon monoxide, carbon dioxide, nitrogen dioxide, and sulfur dioxide (Johnson 1983). Radon in homes accumulates from underground sources hidden from the occupants (Nero 1985), but arsenic is usually airborne (Albert 1985, Patrick and Peters 1985, Baird et al 1985). While the situation is often difficult in work environments, it is often no better at home (cf. Johnson, 1983, Raloff 1985, Hicks 1984). Often the detection of indoor pollution, which is frequently made worse by weather tight buildings, known as the "tight building syndrome," is complicated by relatively poor detection systems (Michaels 1984).

Working outdoors also has its problems. Construction and maintenance crews, farmers and ranchers and year-round workers in the frozen food industry must be concerned about the amount of time spent in the cold (Polakoff 1982). Exposure to ongoing hazards in individual settings may be estimated on the basis of time budget data. For example, an estimated 500,000 U.S. homes contain urea formaldehyde of varying concentrations (Johnson 1983). When divided by the 82.4 million households in the U. S. this represents a crude exposure rate of $6.07 * 10^{-2}$. But refining this estimate by the 66.9 percent of the time spent in the home yields an estimated exposure rate of $4.06 * 10^{-2}$. If we are only concerned with sleep or bedroom exposure, we might estimate the probability of exposure as a function of proportion of households and proportion of time at home asleep, yielding and exposure rate of $2.11 * 10^{-2}$. We can also be less concerned if we find a linkage between day light hours, and in-home pollutents (e.g., should we find that solar heat releases some noxious gas into the home). Because 44.6 percent of the period between 8am and 4pm being spent in the home, the refined exposure rate is $2.83 * 10^{-2}$. Furthermore such gas can dissipate prior to the concentrated exposure associated with evening and night-time occupation. The relatively basic time budget analysis presented here demonstrates the potential exposure as serious. It also flags the importance of within household variations in concentrations of ongoing hazards. Certainly airborne toxin with respiratory exposure pathways are particularly harmful indoors where the most time is spent. The percent of time by period of the day and eleven activities is presented in Table 1.

In Silva et al (1985), an activity systems model is developed to estimate potential exposure related to 60hz electrical fields adjacent to long-distance high voltage power lines. Using time budget data, the model simulates the activities of farmers and others who engage in outdoor activities near high voltage power lines. By combining the electrical properties of the transmission line with the activity data, estimates of annual kilovolts/meter-hour are generated.

Sudden Impact Hazards and Emergency Management

Exposure rates for more sudden hazards may also be estimated as a function of the time-space distribution available in time use data. The consequences of sudden impact hazards such as earthquakes, tornados, flash floods and toxic chemical spills are directly related to how we use our time. For example, mid-day earthquakes are likely to have more human consequences in large cities than night-time or weekend events of similar size. This results from the daily migration of the workforce in communities to and from work locations. Tornadoes, floods other hazards impacting residential areas during night-time or weekend hours will threaten many more people than the same hazard during work-day periods. The risk of shipping toxic chemicals through some areas may be reduced by scheduling such activities to take advantage of time use information -- the associated catastrophic potential may be reduced.

The distribution of human populations may be estimated on the basis of time use data. Emergency planners may begin to anticipate the kinds of problems presented by emergencies occurring at different times of the day, and days of the week. Time budget analysis shows that the often dreaded night time disaster may prove less ominous than anticipated. While darkness no doubt hampers mitigation efforts, households are most likely to be together at home during these periods. In as much as households prefer to take emergency mitigation actions together, (Rogers and Nehnevajsa 1984, Mileti et al. 1975), the family unit is already united and can concentrate directly on adaptive emergency response.

In addition to the relative advantage of inadvertently being in a comparatively safe location during the impact of a sudden impact hazard, emergency management is enhanced by a thorough understanding of the time budget implications for dissemination of the warning message, notification of appropriate emergency activity, and the likelihood of adaptive mitigative action. The window provided by the electronic media is directly related to an emergency manager's ability to disseminate emergency warning to potentially impacted communities. The relatively limited media window during the day-light and dead-of-night hours underscores the need for alerting systems to get people "tuned in" to their radios and televisions. Planning for the late-night dissemination of warning is greatly enhanced through the probabilistic modelling of the processes and an appreciation of the proportion of the population awake during the affected periods. A detailed analysis of the contagion of the warning in the dead-of-night hours based on the proportion of the population awake, the likelihood of arousal among those sleeping, the likely dissemination of warning within households, the likelihood of inter-household contact, household size, and age distribution has been developed to provide emergency management insight for nuclear power plant emergency plans (Nehnevajsa 1985).

CONCLUSIONS

This paper has highlighted a few uses of time budget data and analysis for risk management. The more global categories of activity used here were designed to demonstrate the overall usefulness of the time budget approach to risk management. Three important aspects of risk management are highlighted; 1) the estimation of exposure to ongoing hazards, 2) estimating the probability of exposure to the catastrophic potential of more sudden hazards, and 3) examining emergency management implications of population distribution throughout the day.

While the rich data base provided by the time budget approach has been aptly demonstrated, the depth of the risk management potential has been but touched upon. Specific risk potentials will require detailed analysis of particular activities, the distribution among people, geographic location, day of the week, season of the year and time of day. Time budget data provide such richness and depth in part because they reflect action; not merely attitudes bearing on acceptability, but action reflecting varying degrees of acceptability. Perhaps in this vein time budget data may be used to provide foundation for public perception of risk and its associated acceptability. In any event, daily exposure to hazards of various kinds may be appropriately traced through time budget data. Through careful examination of daily time budgets, legislators, regulators, and risk managers may better focus: a) attention on hazards with the most significant exposure-consequence implications, b) appropriate and effective standards may replace blanket assumptions of safety, c) risk mangers may focus limited resources on issues of great catastrophic potential, and d) emergency managers may better prepare for the most likely event-exposure-consequence chains, by taking advantage of likely daily activities in specific locations. For it is through these actions that risk managers can earn the public's confidence and trust, so much a part of effective risk management.

We have taken a positive view about the potential usefulness of time budget data and analysis for risk management applications; however, some caveats are required. Most of the applications we have discussed have not been tried in practice. Hence, only a few risk assessments have been based on time budget analyses, to our knowledge, and these have been covered herein. Most of what we have presented remains untried, and therefore must be subjected to the validation of real applications. While our analysis suggests that the time budgets of adult Americans are very similar across demographic groups, seasons of the year, and other variables, it is certainly possible that subpopulations may exhibit quite distinct time budgets, and are too infrequently represented in the Michigan data base to influence the overall results, or to be analyzed as a separate group[4]. For example, the time budgets of farmers are somewhat different from other working subpopulations, because farmers work longer hours than most other Americans (Silva et al 1985). In summary, we believe our suggestions will prove to be a valued contribution to risk management, while understanding that much more needs to be done.

REFERENCES

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4. In analyses not reported here, we have learned that the time budgets of adult Americans do not vary greatly when we compare seasons, men and women, young, middle aged and the elderly for the eleven types of activity considered here. We are continuing these analyses to discover the variables that significantly modify the structure of time budgets.