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RISK PERCEPTION, RISK EVALUATION AND HUMAN VALUES: COGNITIVE BASES ACCEPTABILITY OF A RADIOACTIVE WASTE REPOSITORY

JULY 1981

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Prepared for the the Waste Management Systems Studies Program
of the Pacific Northwest Laboratory of the U.S. Department
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Human Affairs Research Centers

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EXECUTIVE SUMMARY

Public acceptance of radioactive waste management alternatives depends in part on public perception of the associated risks. Three aspects of those perceived risks were explored in this study: 1) synthetic measures of risk perception based on judgments of probability and consequences, 2) acceptability of hypothetical radioactive waste policies, and 3) effects of human values on risk perception. Both the work on synthetic measures of risk perception and on the acceptability of hypothetical policies included investigations of three categories of risk: 1) Short-term public risk (affecting persons living when the wastes are created), 2) Long-term public risk (affecting persons living after the time the wastes were created), and 3) Occupational risk (affecting persons working with the radioactive wastes). The human values work related to public risk perception in general, across categories of persons affected.

Respondents were selected according to a purposive sampling strategy, with emphasis both on sampling the general public in specific geographical locations and on sampling the memberships of established groups. The study thus was not designed to lend itself to making probability statements about particular populations, especially that of the United States as a whole; instead, it was designed to explore comparisons among established groups. Six groups were selected on the basis of the interests of their members in risks associated with industrial facilities. The six included:

1) Nuclear Engineers (a national organization of nuclear engineers), 2) Chemical Engineers (a national organization of chemical engineers), 3) Science Writers (a national organization of science writers), 4) Environmentalists (one West Coast, one East Coast, and one national environmental group), 5) Hazardous Facility Communities (residents of six communities in which potentially hazardous industrial facilities are located), and 6) General Communities (residents of six communities chosen without regard to hazardous industrial facilities). Questionnaires were delivered to potential respondents using standard survey mailing procedures; a total of 819 respondents provided usable data.

In the first of three studies described in this report, respondents were asked to make three sets of judgments in sequence, first on the likelihood of significantly bad effects, then on the recall of risk incidents, and, finally, on the tragedy of fatalities. The likelihood judgments were included as indicators of subjective probability, the recall judgments as indicators of a possible source of the likelihood judgments and the tragedy judgments as indicators of perceived consequences. Three judgments were made within each of these sets, one each for Short-term public, Long-term public and Occupational risk. Synthetic measures of risk perception were calculated as the products of the likelihood judgments times the tragedy judgments.

For the sample as a whole, significantly bad effects due to nuclear wastes were judged slightly more likely in the Occupational category than in the Long-term public category; both those categories were judged more

likely to have bad effects than the Short-term public category. There were differences among groups on all three risk categories especially on Long-term public. Nuclear Engineers always produced the lowest likelihood estimates, and Environmentalists always produced the highest. For all respondents, about 25% of the variance in likelihood judgments was associated with recall and tragedy judgments; likelihood judgments were the products of a variety of complex processes and based only in part on frequency (recall) and salience (tragedy) information. The synthetic measures of risk perception, along with a measure including both risks and benefits, were related to a measure of the acceptability of nuclear power. Results showed that a maximum of 82% of the acceptability variance could be associated with risks and benefits as measured. Factors other than risks and benefits thus appeared to have relatively little independent effect on acceptability. These results also provided some evidence that synthetic measures of perceived risk, calculated on the basis of likelihood and consequence judgments, contained information similar to that produced by wholistic risk judgments.

The second study required respondents to judge the acceptability of hypothetical radioactive waste disposal methods. Those acceptability judgments were based on levels of risk (less, same, or more than the present system) in three categories: Short-term public, Long-term public and Occupational. Results showed that Occupational risk was less important than the other two categories for all groups of respondents, especially for the Chemical and Nuclear Engineers. For most groups, Short-term public risk was approximately as important as Long-term public

risk. For the Environmentalists and Science Writers, however, Long-term was slightly more important than Short-term public. With some exceptions, increases in risk affected greater changes in acceptability than did decreases. Following the judgment task, respondents completed a set of items inquiring about the processes they had used. Results indicated that respondents' self-reports were very similar to the statistical description of their judgment policies. This strong correspondence between the two techniques was interpreted as evidence for the accuracy of each. It was concluded, therefore, that respondents demonstrated accurate self-insight. The methodological significance and limitations of this study were discussed in relation to the results of studies that focused on similar content but used different methods.

In the third and final study, respondents were asked to rate the relative importance of each of a set of human values. Some of the respondent groups had value systems that were very much alike. Specifically, the General Communities and the Hazardous Facility Communities were much alike in value importance rankings, as were the Science Writers and Environmentalists and as were the Chemical Engineers and Nuclear Engineers. There were a few exceptions to this generalization. The Hazardous Facility Communities placed more importance on a world of beauty than did the General Communities; the Environmentalists placed more importance on future security than did the Science Writers; and the Nuclear Engineers placed more importance on a world at peace than did the Chemical Engineers.

The four major differences in value importance were among the pairs of groups. The Science Writers and Environmentalists placed more importance both on a world at peace and on a world of beauty than did the other four groups. However, the Science Writers and Environmentalists placed less importance both on family security and on national security than did the other four groups. These differences in the importance placed on certain values likely serve as a partial determinant of the differences in risk perception that were also exhibited by these groups..

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INTRODUCTION

In a 1969 article, Starr presented historical data on the levels of risk that existed in each of a number of different societal activities. He concluded from his data that there are two different classes of activities, voluntary and involuntary, which have significantly different levels of "acceptable risk." The acceptability of a given level of risk, he noted, was much higher for voluntary activities than for involuntary activities.

Such inferences from historical records, commonly referred to as the "revealed preference" approach, have the advantage that they are based upon people's actual behavior and are not, as Rappaport (1974) noted, contaminated by strategic responding. With the "expressed preference" approach on the other hand, it is possible to carefully question respondents and to obtain the reasons for their preferences directly from them. As a result, the expressed preference approach may be able to provide specific answers rather than speculation as to what are the psychologically meaningful differences in the acceptability of risky activities (see Fischhoff, et al., 1978).

Starr's distinction between voluntary and involuntary activities suggests that the public's evaluations of technological activities, such as nuclear waste management, might be determined by perceptions of where, along the voluntariness continuum, the activities associated with this technology can be placed. A complicating factor arises when one

considers that the apparent voluntariness of the risks of sophisticated technological activities may be related to proximity (either geographic or temporal) to technological activities. Support for an association between temporal proximity and voluntariness can be found in a study by Maynard, et al. (1976). Many respondents in that survey gave a greater weight to Long term public safety than to Short term public safety. This result could be interpreted as indicating that it is more important to avoid imposing risks on those who are not voluntarily assuming them (e.g., future generations) than on those who could, by their acceptance of current energy policies, be assumed to be voluntarily accepting the risks of those policies.

Further confirmation of the importance of the voluntariness dimension could be derived from an extension of the expressed preference method to assess the importance of avoiding occupational risks. Workers may not have perfect knowledge of the risks to which they may be exposed or have perfect freedom to choose another occupation even if they wish to avoid the risks associated with their jobs. Nonetheless, it is likely that workers would be generally presumed to be bearing the risks more voluntarily than members of the public at large.

Evidence of the significance of the voluntariness dimension can be convincing only if a number of different tests of the hypothesis are conducted. One test would rely on judgments by respondents of the acceptability of hypothetical waste management policies characterized by their levels of risk in each of these three categories. If judgments of acceptability differed appropriately as a function of risk category, this would support the hypothesis. The significance of the three categories

could also be studied by assessing respondents' judgments of both event probability and event consequences within each of the three risk categories. If systematic differences among the categories exist in either the judgments of probability or consequences, this would also provide support for the hypothesis.

As would be the case for global measures of perceived risk, synthetic measures of perceived risk--constructed by the investigator from a combination of the measures of the constituent parts--can be related to independent measures of the respondents' attitudes toward nuclear power. In this way, the magnitude of the effect of perceived risk on acceptability can be assessed. If the synthetic risk measure alone can account for all of the reliable variance in acceptability, this would suggest that perceived risk alone is a sufficient basis for estimating the acceptability of a technological activity.

The measures of relative importance provided by the acceptability task should also be compared with the respondents' own reports of how their judgments were made. Convergence between these two sets of measures would indicate that each generated good representations of respondents' judgment processes. If convergence were found, then, we could conclude that both tasks were, in fact, measuring what they were supposed to be measuring.

Although a judgment task such as the policy acceptability task is commonly considered to assess the relative impacts of the three risk categories on respondents' judgments (e.g., Adelman and Hammond, 1976), this statement is true only in a limited sense. Any task can assess the relative impacts of attributes on judgments only within that task. The utility or validity of that assessment depends on how representative the

task is of other judgment situations. A task that is of limited generalizability will produce results that are misleading if applied to other situations. In order to avoid such misapplications, the results derived from fixed-format responses, such as those discussed here, should be contrasted with results that are derived from free response techniques, such as those reported by Earle (1981).

In addition to the studies of risk perception and policy acceptability, this report includes an investigation of differences among respondent groups in the basic values that they emphasize. Recent work by Rankin (Rankin & Nealey, 1978; Rankin, 1981) has demonstrated the usefulness of the Rokeach value concept (1968; 1973) for explaining why members of the public think the way they do regarding nuclear power. In the present study, respondents' values are explored within the context of choices among energy technologies and discussions about siting, building and licensing energy facilities. The differences in values found among respondent groups are discussed in relation to possible differences in risk perception. Finally, these speculations on the relations between values and risk perception are compared with the measures of risk perception generated in the first study in this report.

RESPONDENTS

Sampling

A purposive or "judgmental" sampling strategy (Babbie, 1973:106-108) was used in the present study. Purposive sampling, also known as "theoretical sampling" (Glaser & Strauss, 1968:41-62), "scope sampling" (Willer, 1967:97-115) and "sampling of publics" (Blumer, 1948:542-549), is characterized by the sampling of the memberships of established groups. The selection of the established groups is guided by the research questions being studied: those groups are selected that would most efficiently provide the information required. Purposive sampling is far more efficient than probability sampling, which involves drawing a well-defined sample from a well-defined population. The degree to which a sample is representative of a population is statistically assured with probability sampling but not with purposive sampling. Since it is not a purpose of the present study to make probability statements about particular populations, the assured representativeness of population sampling is not required. This study is designed to explore comparisons among established groups, and purposive sampling allows those comparisons to be made efficiently.

Groups of potential respondents were selected on the basis of the interests of their membership in risks associated with industrial facilities. Six groups were selected:

1. Nuclear Engineers: a national organization of nuclear engineers.
2. Chemical Engineers: a national organization of chemical engineers.
3. Science Writers: a national organization of science writers.
4. Environmentalists: two regional (West coast and East coast) environmental groups and one national environmental group.
5. Hazardous Facility Communities residents of six communities in which potentially hazardous industrial facilities are located.
6. General Communities: residents of six communities chosen without regard to hazardous industrial facilities.

Groups 1, 2, 3 and 4 include established groups. Individual respondents within each of these groups were randomly selected from membership lists. Groups 5 and 6 consist of nominal groups, formed only on the basis of geographical proximity. Although the residents of the various communities are treated in subsequent data analyses as though they were members of established groups, there is no intent in this study to make statements about specific communities. What is intended are comparisons between the group of respondents living in Hazardous Facility Communities and the group of respondents living in General Communities, as well as comparisons among these two groups and the other four groups of respondents.

The six communities in the Hazardous Facility Communities group were selected on the basis of geographical diversity and type of hazardous facility:

1. Red Wing, Minnesota (nuclear power plant)
2. Waterford, Connecticut (nuclear power plant)
3. Everett, Massachusetts (liquified natural gas terminal)
4. Savannah, Georgia (liquified natural gas terminal)
5. Forsyth/Colstrip, Montana (coal-fired power plant)
6. Pueblo, Colorado (coal-fired power plant)

The hazardous facilities identified above are not necessarily the only potentially hazardous industrial facilities in each of the communities (Pueblo, for example, also contains a large steel mill). The main sampling strategy was to select communities in which the residents would likely be aware of the existence of a hazardous facility in their town. Thus, the Hazardous Facility Communities tend to be smaller than the General Communities.

Selection of the six communities in the General Communities group was based on geographical diversity and size. The six geographic regions in the United States used by Cambridge Reports (cited in Melber, et al., 1979) were adopted in this study; one community was selected from each region:

1. San Francisco (Pacific region)
2. Houston (Central region)
3. Chicago (Midlands region)
4. Detroit (Industrial region)
5. Boston (Northeast region)
6. Atlanta (South region)

Each of the six General Communities is one of the major cities in its geographic region. Large cities were selected on the grounds that a given individual in a large city would be less likely to live close to and be aware of a specific hazardous industrial facility than would a resident of a smaller community in which a major industrial facility is known to exist. Compare, for example, a resident of San Francisco and a resident of Red Wing. What industry there is in San Francisco is unlikely to intrude on the life of the average resident; the typical resident of Red Wing, on the other hand, is highly likely to be aware of the nuclear power plant located there. This contrast is based on the general notion that the large numbers of people, the extensive residential areas and the great variety and complexity of the surrounding environment all work to make it less likely that residents in the relatively large General Communities will live close to and be aware of a particular hazardous industrial facility than would residents in the relatively small Hazardous Facility Communities. For both the Hazardous Facility Communities and the General Communities, individual residents were randomly selected from the local telephone directory.

Questionnaire Mailing Procedures

The questionnaire was delivered to all respondents in the summer of 1980 through the use of a slight variation of a standard mailing procedure (Dillman, 1978). Since the ratio of returned questionnaires to those mailed tends to be negatively affected by questionnaire length exceeding 11 pages (Dillman, 1978:54-57), the material to be covered was divided into two questionnaires. Questionnaire #1 was 10 pages in

length, contained seven sections and was mailed to 50% of the potential respondents in each of the six groups. Questionnaire #2 was twelve pages in length, contained seven sections and was mailed to the remaining 50% of the potential respondents. The seven sections in each of the two questionnaires consisted of two sets: a) three tasks common to both questionnaires; and b) four sections unique to each questionnaire. Due to this arrangement of tasks, there are three distinct sets of respondents: a) Set #1, those who responded to the tasks unique to Questionnaire #1; b) Set #2, those who responded to the tasks unique to Questionnaire #2; and c) Set #3, those who responded to the tasks common to both questionnaires (i.e., the total set of respondents). These three sets of respondents are discussed later in this section of the report.

The questionnaire mailing procedure consisted of the following steps:

1. Advance notice letter:

Sent to all potential respondents three days before the questionnaire. Mailed first class in a business-sized envelope.

2. First questionnaire mailing:

Sent to all potential respondents (50% Questionnaire #1, 50% Questionnaire #2). In an effort to obtain a balanced distribution of male and female respondents in the Hazardous Facility and General Communities groups, 50% of the accompanying letters for each questionnaire contained a request for a male respondent if possible, the remaining 50% of the accompanying letters contained a request for a female respondent. The accompanying

letters for the other groups of potential respondents contained no reference to sex. Each individual questionnaire together with its accompanying letter and an addressed, postage-paid business reply envelope was mailed first class in a 9" x 12" manila envelope.

3. Second questionnaire mailing:

Sent to all potential respondents from whom neither a returned questionnaire nor an indication of non-deliverability was received within twelve days of the first mailing. The enclosures in the mailing were identical to those in the first mailing, except of course that the accompanying letter referred to the lack of response to the earlier mailing.

4. Third questionnaire mailing:

Sent to all potential respondents from whom neither a returned questionnaire nor an indication of non-deliverability was received within twelve days of the second mailing. The enclosures in this mailing differed from those in the second mailing only in that the accompanying letter referred to the lack of response to the two previous mailings and stated that the third mailing would be the last. Whereas the first and second mailings were mailed first class, the third mailing was sent first class, Special Delivery.

5. Response deadline:

In order to facilitate orderly data processing, no responses received later than a deadline set at three weeks following the final mailing were included in the analyses.

Response Rates

A summary of the response rates (Dillman, 1978:49-53) for all of the groups included in this study is presented in Table 1. The seven columns in the table are defined as follows:

1. Sent: The number of questionnaires mailed in the first mailing; the gross number of potential respondents.
2. Not Deliverable: The number of questionnaires returned by the Post Office due to their inability to locate the addressee.
3. Potential Respondents (Net): The number of potential respondents who presumably received a questionnaire; the number sent minus the number not deliverable.
4. Returns, Acceptable: The number of questionnaires returned that included usable data.
5. Returns, Unacceptable: The number of questionnaires returned that did not include usable data.
6. Returns, Total: The sum of the Returns, Acceptable and Unacceptable.
7. Percentage Returned: Total Returns divided by Potential Returns. This is the response rate.

TABLE 1
Response Rates for All Groups

Name of Group	Sent	Not Deliverable	Potential Respondents	Returns, Acceptable	Returns, Unacceptable	Returns, Total	Percentage Returned
General Communities							
San Francisco	103	21	82	31	4	35	42.7
Houston	119	39	80	22	2	24	30.0
Chicago	116	23	93	22	15	37	39.8
Detroit	124	14	110	36	9	45	40.9
Boston	116	22	94	40	5	45	47.9
Atlanta	119	25	94	33	5	38	40.4
TOTAL	697	144	553	184	40	224	40.5
Hazardous-Facility Communities							
Red Wing, Minnesota	126	33	93	40	7	47	50.5
Waterford, Connecticut	118	12	106	52	6	58	54.7
Everett, Massachusetts	112	20	92	34	5	39	42.4
Savannah, Georgia	115	25	90	26	8	34	37.8
Forsyth/Colstrip, Montana	112	6	106	33	5	38	35.8
Pueblo, Colorado	111	20	91	44	7	51	56.0
TOTAL	694	116	578	229	38	267	46.2
Environmentalists							
Western	49	1	48	35	4	39	81.2
Eastern	100	1	99	75	3	78	78.8
National	98	1	97	65	8	73	75.2
TOTAL	247	3	244	175	15	190	77.9
Nuclear Engineers	96	0	96	82	1	83	86.4
Chemical Engineers	99	4	95	72	2	74	77.9
Science Writers	206	3	203	77	20	97	47.8
GRAND TOTAL	2039	270	1769	819	117	936	52.9

The total response rate for all groups was 52.9%. The response rates for the six major groups ranged from 40.5% for the General Communities to 86.4% for the Nuclear Engineers. These different response rates were not surprising. On the basis of previous studies (e.g., Rankin and Nealey, 1978; Dillman, 1978:29-32), one would expect that a questionnaire dealing with a specific topic such as nuclear waste management would evoke higher response rates from established groups whose members are known to be interested in that topic than from groups whose members have no known interest in it. This pattern of response rates holds true for all of the groups in the study. The General Communities, the Hazardous Facility Communities and the Science Writers all had response rates in the 40's. The only surprise here is the Science Writers, a group presumably more interested in technical topics than the general public. Based on an analysis of the Incomplete Returns (see Lindell and Earle, 1981), the relatively low response rate for the Science Writers appeared to be due to the lack of time and to ethical considerations. The Environmentalists, the Nuclear Engineers and the Chemical Engineers had response rates in the 70's or 80's, as expected. The total response rate of 52.9% was composed, then, of high response rates and moderate response rates. The moderate response rates were associated with lack of specific interest in the central topic of the survey.

As pointed out above in the section on mailing procedures, respondents were grouped into three distinct sets: a) Set #1, those (N=428) who responded to the tasks unique to Questionnaire #1; b) Set #2, those (N=391) who responded to the tasks unique to Questionnaire #2; and

c) Set #3, those (N=819) who responded to the tasks common to both questionnaires (the total set of respondents). Complete analyses of the demographic characteristics of these respondents are presented in a companion report (Lindell and Earle, 1981).

The demographic comparisons among the respondent groups are summarized here in Table 2. The entries in Table 2 compare the groups on the left margin with those on the top margin. Thus, for instance, the General Communities had a greater proportion of male respondents than did the Environmentalists. Only statistically significant differences are entered.

TABLE 2

Summary of Demographic Comparisons Among Respondent Groups

Group	Character- istics	General Communities	Hazardous Facility Communities	Environ- mentalists	Science Writers	Chemical Engineers	Nuclear Engineers
General Communities	Sex			+ Male		- Male	- Male
	Education		+	-	-	-	-
	Employment Status		+ students	+ students	- employed	- employed	- employed
	Occupation		- blue collar + white collar	+ blue collar - education & professionals	- writers	- engineers	- engineers
	Income		+	-	-	-	-
	Age						older
Hazardous Facility Communities	Sex			+ male		- male	- male
	Education	-		-	-	-	-
	Employment Status	+ retired		+ retired	- employed	- employed	- employed
	Occupation	+ blue collar, - white collar & professionals		+ blue collar, - education & professionals	- writers	- engineers	- engineers
	Income	-		-	-	-	-
	Age						older
Environ- mentalists	Sex	- male	- male		- male	- male	- male
	Education	+	+			-	-
	Employment Status	+ retired		+ retired	- employed	- employed	- employed
	Occupation	- blue collar, + education & professionals	- blue collar, + education & professionals		- writers	- engineers	- engineers
	Income	+	+		-	-	-
	Age						older

TABLE 2 (continued)

Group	Character- istics	General Communities	Hazardous Facility Communities	Environ- mentalists	Science Writers	Chemical Engineers	Nuclear Engineers
Science Writers	Sex			+ male		- male	- male
	Education	+	+			-	-
	Employment Status	+ employed	+ employed	+ employed		- employed	- employed
	Occupation	+ writers	+ writers	+ writers		- engineers	- engineers
	Income	+	+	+		-	
	Age						older
Chemical Engineers	Sex	+ male	+ male	+ male	+ male		
	Education	+	+	+	+		-
	Employment Status	+ employed	+ employed	+ employed	+ employed		
	Occupation	+ engineers	+ engineers	+ engineers	+ engineers		
	Income	+	+	+	+		-
	Age						older
Nuclear Engineers	Sex	+ male	+ male	+ male	+ male		
	Education	+	+	+	+	+	
	Employment Status	+ employed	+ employed	+ employed	+ employed		
	Occupation	+ engineers	+ engineers	+ engineers	+ engineers		
	Income	+	+	+		-	
	Age	younger	younger	younger	younger	younger	

SYNTHETIC MEASURES OF RISK PERCEPTION BASED ON JUDGMENTS OF PROBABILITY AND CONSEQUENCES

Based on an analogy to such analytical models as expected value, expected utility and risk assessment (Whyte & Burton, 1980), public risk perception can be analyzed into two constituent parts, subjective judgments of probability and subjective judgments of consequences of undesirable outcomes (Starr & Whipple, 1980). The tasks described below utilize this perceived risk framework, but the validity of the framework in describing what persons actually do when they make risk judgments is not assumed. Judgments of probabilities and consequences are logically required by certain models of risk assessment, but members of the public may or may not consider these two factors, separately or together, in any specific instance. (Applications of this general approach to attitudes toward nuclear power and voting on a nuclear initiative can be found in Woo & Castore, 1980; and Bowman & Fishbein, 1978.)

In the present study, the analysis of perceived risk into perceptions of probabilities and consequences is applied to public perception of risks associated with radioactive waste management. Different aspects of public perception of these risks have been topics of previous reports (Lindell, Earle, Hébert & Perry, 1978; Lindell, Earle & Perry, 1980; Lindell & Earle, 1980). In none of these previous studies, however, have respondents been asked both to judge the probability of a set of events

and to evaluate their potential consequences. The events judged by respondents in this study were based on three categories of risk that have been developed from several earlier studies (e.g., Maynard, et al., 1976). The risk categories and the definitions given respondents were:

Short-term public risk. "Short-term risks are those risks which occur from approximately the time that the wastes are generated up to about 100 years. Short-term public risks are thus faced by those who benefit from the nuclear processes that produced the wastes."

Long-term public risk. "Long-term risks are those which take place in the period beyond the first 100 years and last through the gradual decay of the radioactivity to harmless levels. Long-term public risks are thus faced by those who receive no direct benefits from the nuclear processes that produced the wastes."

Occupational risk. "Occupational risks are the risks to persons who work with radioactive wastes, especially the employees at a radioactive waste disposal site. Occupational risks thus confront those who receive pay for working in the nuclear industry."

After having been given these definitions, respondents were asked to make three sets of judgments in sequence, first on the likelihood of significantly bad effects, then on the recall of risk incidents, and, finally, on the tragedy of fatalities. The likelihood judgments were included as indicators of subjective probability, the recall judgments as indicators of a possible source of the likelihood judgments and the tragedy judgments as indicators of perceived consequences. Three judgments were made within each of these sets, one each for Short-term public, Long-term public and Occupational risk. This task was contained in Questionnaire #2, and the respondents therefore were those of Set #2. The instructions for each set of judgments follow:

1) Likelihood of Significantly Bad Effects: How likely do you think it is that there will be significantly bad effects due to radioactive wastes? The term "significantly" means "bad enough" to be of concern to you. The likelihood of a significantly bad effect can be indicated by assigning a number between zero (0) and one hundred (100). Zero would indicate your belief that there is no likelihood that a significantly bad effect will occur; 100 would indicate your belief that a significantly bad effect is certain to occur. Please indicate the likelihood of significantly bad effects by assigning a number between 0 and 100 to each of the three categories of risk.

2) Recall of Risk Incidents: To what extent can you recall hearing or reading about incidents (or the possibility of incidents, fictional or real) in which radioactive wastes had significantly bad effects on the three categories of risk? Please indicate the extent of your recall by circling one of the answer choices along side each risk category.

3) Tragedy of Fatalities: The circumstances associated with a death affect its impact on those who read or hear about it. The accidental death of a young child, for example, may be considered more tragic by some persons than the death by illness of a very old person who has led a full life. Consider deaths due to the three risk categories. If an incident should occur that resulted in fatalities, how tragic to you would be the deaths due to these three causes? Please indicate how tragic to you deaths due to the radioactive waste disposal risk categories are by circling one of the answer choices beside each category.

Results

Likelihood judgments. Respondent groups differed both in the ways they distributed their likelihood judgments along the 100 point scale and in their mean likelihood judgments. The differences in distributions for Short-term public, Long-term public and Occupational bad effects are illustrated in Figures 1, 2 and 3, respectively. Figure 2, showing likelihood judgments for Long-term public bad effects, demonstrates the group differences most strongly. For clarity, only the data for the entire sample of respondents, the Environmentalists and the Nuclear Engineers are shown; these groups represent the mean and the two extremes. The shape of the distribution for the total group is that of a flattened W: the most frequently selected likelihood levels were those near 0.00, 1.00

and 0.50, the end-points and mid-point of the scale. The distributions (not shown) for the two public groups, General Communities and Hazardous Facility Communities, also resembled flattened W's. This result indicates a general tendency in heterogeneous groups to view the likelihood of the defined event as certain to occur, certain not to occur, or a (fifty-fifty) toss-up. More homogeneous groups with extreme views regarding the defined event, of course, tended to produce judgments located at one of the end points. For example, 79.0% of the Nuclear Engineers judged the likelihood of Long-term public bad effects due to radioactive wastes as 0.20 or less (see Figure 2). The modal judgment, accounting for 47.4% of the Nuclear Engineers total judgments, was 0.0. By way of contrast, 70.6% of the Environmentalists' judgments were 0.80 or more; their modal judgment was 100.0, which represented 51.8% of their total judgments (see Figure 2).

The Nuclear Engineers and the Environmentalists differed strongly in their likelihood judgments for all three categories of bad effects due to nuclear wastes. In evaluating these differences, it must be kept in mind that the event judged by respondents was subjectively defined. Thus, effects of nuclear wastes that may have been bad enough to be of personal concern for the Environmentalists may have been of little concern for the Nuclear Engineers. In support of this observation, it should be noted that Maynard, et al. (1976:68), found that Environmentalists and Nuclear Engineers differed significantly in their ratings of the acceptability of deaths due to a radioactive waste disposal facility. Environmentalists rated 1 death per year as moderately satisfactory while Nuclear Engineers rated 100 deaths per year as moderately satisfactory.

Figure 1. Likelihood of short-term public bad effects due to radioactive wastes.

Figure 2. Likelihood of long-term public bad effects due to radioactive wastes.

Figure 3. Likelihood of occupational bad effects due to radioactive wastes.

The mean likelihood judgments for all six groups of respondents are shown in Figure 4. Over all groups, except Environmentalists, Occupational effects were judged slightly more likely than Long-term public effects and considerably more likely than Short-term public effects. The groups differed most strongly on Long-term public effects, the category given the lowest likelihood by the Nuclear Engineers and the highest by the Environmentalists. Long-term public effects were considered more likely than Short-term public effects by all groups except the Nuclear Engineers. Occupational effects were judged as more likely than Long-term public effects by all groups except the Environmentalists. The order of groups, from the one with the lowest likelihood judgments to the one with the highest, was invariant across categories of effects.

Recall judgments. Although the respondent groups differed in their recall of risk incidents, the differences among group means on this task were much smaller than those in the likelihood judgment task. As Figure 5 shows, the largest differences among groups were for recall of Long-term public risk incidents. Mean recall of risk incidents for all respondents was highest for Occupational risk, followed by Short-term public risk and then by Long-term public risk. This order among the categories of risk incidents was followed by each of the six groups. The Chemical Engineers were consistently lowest in their recall of risk incidents, while the Environmentalists were consistently highest.

Figure 4. Likelihood of significantly bad effects.

NE = Nuclear Engineers
CE = Chemical Engineers
SW = Science Writers
 $\bar{X}$ = Sample mean

HFC = Hazardous Facility Communities
GC = General Communities
ENV = Environmentalists

Tragedy judgments. As with the recall judgments, the differences among groups were much smaller for judgments of the tragedy of deaths than for likelihood judgments (see Figure 6). Again, the groups differed most strongly on the Long-term public category, with the Environmentalists giving higher tragedy ratings than the General and Hazardous Facility Communities. These groups, in turn, gave higher ratings than the Nuclear and Chemical Engineers. On the Occupational category, the two engineer groups gave lower tragedy ratings than the remaining groups. There were no significant differences among groups on the Short-term public category. The mean tragedy judgment for all respondents was lower for the Occupational category than for the other two categories.

Correlations among judgments. The three sets of judgments described above--the likelihood, recall and tragedy judgments--were correlated with one another to determine whether any interrelationships existed. Significant correlations between likelihood and recall judgments, for example, might indicate that the two types of judgments shared a common judgment process.

In the absence of an unambiguous causal ordering, it is not possible to say with certainty whether the likelihood judgments "cause" the recall judgments, the recall judgments cause the likelihood judgments or if both judgments are made from another factor which is not measured here. Since the recall of risk incidents and the degree of tragedy of incidents would seem to be more basic--in the sense that they seem to be more likely to be preexisting categories of judgment--analyses to be reported below will be analyzed under the assumption that recall of risk incidents and judgments of tragedy do form the basis of judgments of likelihood and not the reverse.

Figure 5. Recall of risk incidents.

CE = Chemical Engineers
 NE = Nuclear Engineers
 SW = Science Writers
 $\bar{X}$ = Sample Mean

GC = General Communities
 HFC = Hazardous Facility Communities
 ENV = Environmentalists

Short-term public risk
 $F = 1.8$
 $p < .10$

Long-term public risk
 $F = 6.2$
 $p < .001$

Occupational risk
 $F = 4.2$
 $p < .005$

Figure 6. Tragedy of fatalities.

NE = Nuclear Engineers
 CE = Chemical Engineers
 SW = Science Writers
 $\bar{X}$ = Sample Mean

HFC = Hazardous Facility Communities
 GC = General Communities
 ENV = Environmentalists

The most striking result for the correlations shown in Table 3 is the absence of any significant correlations for the Nuclear Engineers between the likelihood variable and either of the other two variables. Since all of the likelihood correlations for three of the groups were significant and several correlations for the remaining two groups were significant, the absence of significant correlations for the Nuclear Engineers would seem to indicate that members of that group based their likelihood judgments largely on factors not considered by the other respondents. An alternative explanation for this result is that the low correlations are due to "restriction of range." Remember that the Nuclear Engineers rated the likelihood, recall and tragedy dimensions consistently low. Since there was almost no variation in the ratings there was no possibility for covariation--and hence correlation--to emerge. This problem was probably not present with the Chemical Engineers. Although their recall judgments were highly correlated with likelihood judgments for the Short-term public category, and weakly correlated for the Long-term public category, the recall judgments were uncorrelated for the Occupational category. The Chemical Engineers thus based their likelihood judgments on different factors for each category. The likelihood judgments for both the Science Writers and the Chemical Engineers were only weakly correlated or uncorrelated with tragedy judgments. The Science Writers thus relied more heavily on recall (frequency) information in making their likelihood judgments than they did on tragedy (salience) information. The same was true for Chemical Engineers in the Short-term public category. The correlations between recall and tragedy judgments exhibited a general

TABLE 3

Nuclear Waste Disposal Facility

Correlations between Likelihood Judgments and Recall and Tragedy Judgments

Group	<u>Short-term Public</u>		<u>Long-term Public</u>		<u>Occupational</u>	
	Recall	Tragedy	Recall	Tragedy	Recall	Tragedy
General Communities	** .48	** .34	** .33	** .35	** .30	** .36
Hazardous Facility Communities	** .34	** .36	** .42	** .45	** .37	** .40
Environmentalists	** .53	** .48	** .51	** .32	** .50	** .48
Science Writers	** .58	.29	** .48	.30	** .57	.19
Chemical Engineers	** .72	.29	* .31	* .33	.09	-.28
Nuclear Engineers	.09	.03	.12	.05	.10	.02
TOTAL	** .47	** .34	** .44	** .41	** .40	** .36

Recall-Tragedy Correlations

Group	Short-Term Public	Long-Term Public	Occupational
General Communities	.16	* .23	** .36
Hazardous Facility Communities	** .30	** .44	** .31
Environmentalists	** .40	* .25	** .41
Science Writers	.31	.30	.16
Chemical Engineers	* .36	-.10	.24
Nuclear Engineers	*-.38	-.07	.01
TOTAL	** .20	** .28	** .31

* p<.05

** p<.005

pattern of lower correlations for the technically more sophisticated groups (Science Writers, Chemical and Nuclear Engineers) and higher correlations for the technically less sophisticated groups (General and Hazardous Facility Communities and Environmentalists). There were exceptions to this rule--for example, the low correlations for the General Communities group and the contrasting positive and negative correlations for the Chemical and Nuclear Engineers, respectively, in the Short-term public category.

A clearer understanding of the relationships between likelihood judgments on the one hand and recall and tragedy judgments on the other can be developed through the use of regression equations in which the likelihood judgments are predicted on the basis of both the recall and tragedy judgments. In Table 4, the entries in the R^2 column indicate the degree to which likelihood judgments were predictable, given judgments of recall and tragedy. For General Communities, for example, 26% of the variance in the Short-term public likelihood judgments was predictable on the basis of recall and tragedy judgments. The relative contributions to likelihood judgments of recall and tragedy judgments are indicated by the standardized regression weights. For example, for the Short-term public likelihood judgments of the General Communities recall judgment had a weight of 0.40, which is 1.54 times the 0.26 weight given tragedy judgments. For the General Communities, therefore, recall judgments were more strongly related to likelihood judgments than were tragedy judgments; 74% of the variance of the likelihood judgments, however, was related neither to recall nor to tragedy judgments.

Several results shown in Table 4 deserve special mention. Over all likelihood judgments, an average of about 25% of the variance was associated with recall and tragedy judgments. The percentage of "explained" variance ranged from 1% for the Nuclear Engineers in the Short-term public category to 51% for the Chemical Engineers in the same category. The high percentage of explained variance for the Chemical Engineers was due entirely to the association between their likelihood and their recall judgments. For the Chemical Engineers, likelihood and recall judgments seem to have been generated by a similar process in the Short-term public category. In the Long-term public and Occupational categories, the Chemical Engineers appear to have generated their judgments in differing ways. The Nuclear Engineers were consistent across all three categories; in none of the categories were their likelihood judgments related to either their recall or their tragedy judgments. This result was due to the "restriction of range" effect noted earlier. The Science Writers were also consistent across categories; their likelihood judgments were related to their recall judgments but not to their tragedy judgments. The remaining three groups of respondents exhibited varying combinations of strength of relations between their likelihood judgments and their recall and tragedy judgments.

Within the Short-term public category across all groups, recall was weighted an average of 1.71 times as strongly as tragedy. For the Occupational category, the weighting was 1.48 in favor of recall. In the Long-term public category, however, recall and tragedy were virtually even in average weightings. Thus, frequency information seems to have been more

TABLE 4

Prediction of Likelihood Judgments from Recall
and Tragedy Judgments

Group	Short-term Public			Long-term Public			Occupational		
	Standardized Regression Weights		R ²	Standardized Regression Weights		R ²	Standardized Regression Weights		R ²
	Recall	Tragedy		Recall	Tragedy		Recall	Tragedy	
General Communities	***.40	***.26	***.26	*.25	*.26	** .18	.20	*.30	** .17
Hazardous Facilities Communities	*.24	** .32	***.20	*.25	** .32	***.24	** .31	*.26	***.22
Environmentalists	***.44	** .30	***.40	***.46	.19	***.30	***.39	** .30	***.34
Science Writers	** .54	.05	*.31	*.43	.10	.22	** .58	.01	** .34
Chemical Engineers	***.70	.04	***.51	.33	*.36	*.22	.18	-.32	.11
Nuclear Engineers	.12	.07	.01	.16	.16	.05	.13	.04	.02
TOTAL	***.41	***.24	***.27	***.34	***.30	***.26	***.34	***.23	***.21

* p<.05

** p<.01

*** p<.001

closely associated with likelihood estimates when it contained information about actual past occurrences than when it contained only speculation regarding possible future occurrences. There were, of course, individual group exceptions to this general rule. The Environmentalists and Science Writers, for example, both related recall but not tragedy with likelihood judgments in the Long-term public category.

Risks, benefits and acceptability. One of the primary reasons for studying public risk perception is the relationship between the perceived risks of a technology, for example, and the public acceptability of that technology. Of course perceived risk is only one possible factor in judged acceptability; other factors such as benefits may also affect acceptability. One way to assess the relative contributions of perceived risk and benefit to judged acceptability is to predict acceptability on the basis of both risks and benefits and then compare the relative contributions of the two factors. This procedure was followed using a multiple regression analysis (see Table 5). The dependent variable in the regression analysis was an acceptability scale composed of two items:

1. "The United States should continue to build nuclear power plants." (Answered on a seven-point scale, from Strongly Agree (1) to Strongly Disagree (7).)
2. "In order to meet the energy needs of the United States, how important is it to have more nuclear power?" (Respondents selected one of four alternatives: 1) Extremely important, 2) Somewhat important, 3) Not too important, 4) Not at all important.)

Respondents' scores on these two items were simply added together to produce their acceptability scale scores. The estimated reliability of this scale was assessed using the following formula:

$$\text{Reliability} = \frac{2r}{1+r} ,$$

where r is the correlation between the two items making up the scale (Stanley, 1971, p.380). Reliability can be interpreted as the proportion of true (as opposed to error) variance measured by the acceptability scale. Across groups, the estimated reliability of 0.85 is high, indicating a low proportion of error variance. The estimate of reliability for the Nuclear Engineers group; however, was essentially zero. The reason for this low estimate was the extremely high degree of agreement among the Nuclear Engineers on both items. Specifically, 75.7% of the members of that group marked "(1), Strongly Agree" on both of the acceptability items, demonstrating their strong support for nuclear power. As was the case for the likelihood judgments, this uniformity of response constitutes a "restricted range" that mathematically limits the size of the correlations and, thus, the estimate of reliability. Although the reliability of the Nuclear Engineers' judgments of the acceptability is undoubtedly much higher than zero, these two items cannot be used to provide a quantitative estimate.

The reason for attempting to make a quantitative assessment of reliability is that it indicates the effective upper bound of the proportion of variance that may possibly be related to the predictor variables. This

TABLE 5

Prediction of Nuclear Power Acceptability Scale from a
Risk Scale and a Risk/Benefit Scale

Group	Risk Scale (r^2)	Risk/Benefit Scale (r^2)	Risk and Risk/Benefit Scales (R^2)	Reliability of Acceptability Scale (Proportion of True Acceptability Variance)
General Communities	.42	.58	.61	.81
Hazardous Facilities Communities	.31	.45	.47	.65
Environ- mentalists	.41	.62	.63	.87
Science Writers	.50	.67	.68	.87
Chemical Engineers	.24	.49	.54	.89
Nuclear Engineers	.00	.01	.01	.02
TOTAL	.50	.64	.66	.85

is particularly significant since the apparent upper bound of predictability is $R^2=1.00$. Since, as the discussion of reliability has indicated, not all of the variance in the acceptability scale is reliable variance, it is important to know just how much of the variance is reliable. Then, if the proportion of predictable variance is close to the proportion of reliable variance, one could conclude that all of the relevant predictor variables had been included in the prediction equation.

Two predictor variables were developed from several individual items. The risk scale contained three items:

1. $RISKSTP = (\text{Likelihood of significant Short-term public bad effects due to radioactive wastes}) \times (\text{Tragedy of deaths due to Short-term public bad effects of radioactive wastes})$
2. $RISKLTP = (\text{Likelihood, Long-term public}) \times (\text{Tragedy, Long-term Public})$
3. $RISKOCC = (\text{Likelihood, Occupational}) \times (\text{Tragedy, Occupational})$

Respondents' risk scale scores were determined by summing their scores on each of the risk categories.

$$RISKTOTAL = RISKSTP + RISKLTP + RISKOCC$$

The risk/benefit scale contained four items:

"Compared to the societal benefits of nuclear power, how large are the risks of nuclear waste?"

1. For those who work with the wastes
2. For those who live near disposal sites or transportation routes
3. The public at large
4. For future generations."

On each of these items, respondents selected an answer choice ranging from "Risks greater than benefits" (1) to "Benefits greater than risks" (7). Respondents' risk/benefit scale scores consisted of their total scores for the four items.

Table 5 presents, for each group of respondents, the proportion of the variance of the acceptability scores that was associated with risk scale scores, risk/benefit scale scores and a combination of both the risk and the risk/benefit scale scores. For the total group of respondents, 50% of the acceptability score variance was associated with risk scale score variance. The reliability of the risk scale for the total group of respondents was 0.88. We can therefore see that the maximum percentage of the acceptability scale variance that could be associated with the risk scale scores, given perfect reliability in both scales, would be

$$R^2 = \frac{\text{proportion of acceptability variance associated with risk scores}}{(\text{reliability of acceptability scale})(\text{reliability of risk scale})}$$

$$= \frac{0.50}{(0.85)(0.88)}$$

$$R^2 = 0.67.$$

Thus, 33% of the acceptability variance was based on factors other than risk. That is, the risk scores cannot adequately account for the acceptability scores, even when corrections for unreliability of predictor and criterion measures are made. Factors other than risk alone must be used.

Before leaving the risk scale, we should note the variation among respondent groups in the degree of association between risk and acceptability. Acceptability of nuclear power was more closely associated with the risks of nuclear wastes for groups composed of observers of technology (Science Writers, General Communities and Environmentalists) and less closely associated for groups composed of participants in technology (Nuclear Engineers, Chemical Engineers and Hazardous Facility Communities). As with the reliability of the acceptability scale, these correlations were of course affected by differences among groups in their homogeneity (i.e., within-group variation).

The risk/benefit scale, as shown in Table 5, accounted for 64% of the variance in the acceptability scale. The reliability of the risk/benefit scale was 0.92. The maximum percentage of the acceptability scale variance that could be associated with the risk/benefit scores, given perfect reliability in both scales, therefore would be

$$R^2 = \frac{0.64}{(0.92)(0.85)}$$

$$R^2 = 0.82.$$

The use of benefit/risk factor rather than risk alone increased the amount of explained variance by 15%, from 67% to 82%. Risks and benefits, as measured here, accounted for the major portion of the variance in acceptability of nuclear power, then, leaving only a small proportion of variance related to other, unmeasured factors. Finally, a comparison between the columns of Table 5 referring to the risk/benefit scale used alone and to the risk and risk/benefit scales together show that the addition of the risk scale to the risk/benefit scale produces only a very small positive increment in the predictability of the acceptability scale scores. The risk/benefit scale items appear to have incorporated the information contained in the risk scale items. Since the risk scale scores were calculated using likelihood judgments and tragedy judgments, this result provides some support for the view that risk judgments can be usefully analyzed into separate probability and consequence components.

Summary

Public perception of the risks associated with nuclear wastes was studied through the analysis of separate judgments of the likelihood of (subjectively defined) significantly bad effects and the degree of tragedy associated with deaths due to nuclear waste effects. Three categories of risk were studied: Short-term public, Long-term public and Occupational. In addition to likelihood and tragedy judgments, respondents also indicated the number of risk incidents--fictional or real--they could recall for each category. Respondents' likelihood judgments on a 100 point scale were very low (the event is certain not to

occur), very high (the event is certain to occur) or in the middle (50/50 chance of occurrence). Heterogeneous groups of respondents (e.g., General Communities) had likelihood frequency distributions shaped like flattened W's (high points at the certain not to occur, 50/50 and certain to occur points). Homogeneous groups with extreme views (e.g., Nuclear Engineers and Environmentalists) had distributions heavily skewed to one or the other end of the scale. For the sample as a whole, significantly bad effects were judged slightly more likely in the Occupational category than in the Long-term public category. Both these categories were judged more likely to have bad effects than the Short-term public category. There were differences among groups on all three risk categories, especially, on Long-term public. Nuclear Engineers always produced the lowest likelihood estimates, and Environmentalists always produced the highest.

For all respondents, about 25% of the variance in likelihood judgments was associated with recall and tragedy judgments. There were large differences among groups in the relations among likelihood, recall and tragedy. Groups also differed in the degree of consistency with which likelihood, recall and tragedy were related across the three categories of risk. For example, for Nuclear Engineers likelihood was consistently unrelated to both recall and tragedy. The Chemical Engineers were inconsistent: likelihood was highly related to recall in Short-term public risk but only weakly related to either factor in the other categories. The Science Writers, as a final example, consistently related likelihood to recall but not to tragedy. Over all respondents,

recall (frequency) information was more closely associated with likelihood judgments when it could be referred to actual past occurrences (Short-term public and Occupational) than when it could refer only to speculation about possible future events (Long-term public). Interestingly, this was not true for the critics of nuclear power, the Environmentalists and the Science Writers, who related recall but not tragedy to likelihood judgments in the Long-term public category. In general, these results indicate that the likelihood judgments of significantly bad effects due to nuclear wastes were the products of a variety of complex processes and based only in part on frequency (recall) and salience (tragedy) information. Such a conclusion may be expected with regard to a type of risk with which most persons have had very little experience.

The final set of results dealt with the problem of the relationship between the acceptability of nuclear power on the one hand and both the risks of nuclear wastes and the societal benefits of nuclear power on the other. The analysis showed that a maximum of 82% of the acceptability variance could be associated with risks and benefits as measured. Factors other than risks and benefits thus appeared to have relatively little independent effect on acceptability. These results also provided some evidence that synthetic measures of perceived risk, calculated on the basis of likelihood and consequence judgments, contained information similar to that produced by global risk judgments.

ACCEPTABILITY OF HYPOTHETICAL RADIOACTIVE WASTE POLICIES

This section explores two general problems of policy acceptability within the context of judgments of the acceptability of hypothetical radioactive waste management alternatives. The first problem is one in which persons are asked to judge the acceptability of a set of policy alternatives described only by a limited set of attributes. This is not an uncommon state of affairs: a problem is often structured by one group of persons (e.g., technical experts) and the acceptability judgments are made by another (e.g., the public). In this study, a set of hypothetical nuclear waste management systems were described by their levels of risk in each of three categories: Long-term public risk, Short-term public risk and Occupational risk. The resulting data were analyzed in order to provide statistical representations of the relative importance of each of the three factors and different levels on each factor.

The second problem concerns the correspondence between such statistical descriptions of the acceptability judgments and respondents' own descriptions of their judgment processes. To evaluate the convergence between such statistical representations and direct reports, respondents were also asked to provide information about the processes by which their judgments were made in the task described above. Convergence in the inferences made from these two approaches would produce confidence in the results. Irreconcilable differences between them would cast doubt on the validity of one or the other (or both) as representations of the judgment processes.

Policy Judgments

The context within which respondents were to make their policy judgments was presented in the following instructions:

Most people agree on the need for a system for permanent disposal of radioactive wastes. People disagree, however, over which of several disposal systems should be implemented. Controversy exists because the alternatives differ not only in technical ways, but also in ways that relate to personal values and public policy.

One method of resolving the issue is to find out the attitudes of citizens toward the alternatives and to use that information as a guide. In this part of the survey you are asked to judge the acceptability of hypothetical waste disposal systems. In making your judgments, imagine that you are a citizen who, along with many others, has been asked to make recommendations on different methods for processing highly radioactive nuclear wastes. Nuclear technologists have informed you that the alternatives differ on three major factors: Short-term public risk, Long-term public risk, and Occupational risk.

- . Short-term risks are those which occur from approximately the time that the wastes are generated up to about 100 years. Short-term public risks are thus faced by those who benefit from the nuclear processes that produced the wastes.
- . Long-term risks are those which take place in the period beyond the first 100 years and last through the gradual decay of the radioactivity to harmless levels. Long-term public risks are thus faced by those who receive no direct benefits from the nuclear processes that produced the wastes.
- . Occupational risks are the risks to persons who work with radioactive wastes, especially the employees at a radioactive waste disposal site. Occupational risks thus confront those who receive pay for working in the nuclear industry.

As you judge the acceptability of hypothetical waste disposal methods below you will encounter examples of "tradeoffs" between high risk on one of the factors and low or moderate risk on the others. The levels of risk for each of the three risk categories are given relative to the current system of temporary storage. There are three levels: Significantly Less, Same and Significantly More. The term "significantly" should be given your own personal interpretation; you should consider the actual level of risk to be whatever is "significantly" more or less to you.

Consider the following example:

ALTERNATIVE A

		Very Unacceptable					Very Acceptable
Short-term public	Significantly less						
Long-term public	Same	1	2	3	4	5	6 7
Occupational	Significantly more						

For alternative A you see that Short-term public risk is significantly less than the current system, Long-term public risk is the same as the current system and Occupational risk is significantly more than the current system. On the basis of this information you should make your judgment of the overall acceptability of Alternative A.

PLEASE INDICATE THE ACCEPTABILITY OF EACH OF THE FOLLOWING ALTERNATIVE NUCLEAR WASTE DISPOSAL SYSTEMS BY CIRCLING ONE OF THE ANSWER CHOICES NEXT TO EACH SYSTEM.

Respondents were then presented with 27 alternative systems, consisting of the 27 combinations of three risk categories and three risk levels. This task was contained in Questionnaire #2, and the respondents therefore were of Set #2.

Results

Each combination of a given risk category (e.g., Short-term public) and a given level of risk (e.g., less) appeared in 9 of the 27 alternatives judged by each respondent. The mean acceptability judgments on each combination of risk category and level for each of the six groups of respondents are presented graphically in Figure 7. For the total group of respondents, judged acceptability varied inversely with level of risk, the higher the risk, the lower the acceptability. There was, however, an interaction between risk categories and risk levels. Whereas acceptability steadily declined as risk increased in the Short-term and

Figure 7. Acceptability of alternative nuclear waste disposal systems, by risk category, level of risk and group.

Long-term public categories, acceptability varied relatively little within the Occupational category. This result indicates that Occupational risk was a less significant category of risk for respondents than were the other two. This was true not only of the total group of respondents (in aggregate) but also of each of the six subgroups individually.

While the respondent groups agreed on the relative importance of the three risk categories, they consistently disagreed on levels of acceptability for each of the nine risk category by risk level combinations. As the graphs in Figure 6 show, the Environmentalists and Science Writers were always below the mean, and the Nuclear Engineers, Hazardous Facility Communities and General Communities were always above the mean. The Chemical Engineers, averse to risk increases, were below the mean when risk was significantly more, but above the mean when risk was either significantly less or the same.

Another view of the acceptability judgment results is given in Figure 8. In these graphs, the relative importance of the three risk categories is indicated by the slope of the line: the steeper the negative slope from the "less risk" level to the "more risk" level, the greater the importance of the risk category. The relative lack of importance of the Occupational category can be seen in the fact that it had a shallower slope than the other two categories for each of the six groups. This effect was greatest for the Chemical and Nuclear Engineers. For most of the groups, Short-term and Long-term public risk were of essentially equal importance (the graphs nearly coincide). But for the Environmentalists and the Science Writers, Long-term public risk was

Figure 8. Acceptability of Alternative nuclear waste disposal systems, by group, risk category and risk level.

+++++ Short-term public risk
 --- Long-term public risk
 — Occupational risk

Chemical Engineers

Nuclear Engineers

Total

Figure 8. (continued)

somewhat more important than Short-term public risk. The slope of the graphs also indicates the relative importance of the difference between same and less risk, on the one hand, and the difference between same and more risk, on the other. In most cases, the same-more difference was more important (produced a greater change in acceptability) than the same-less difference. On the whole, respondents indicated greater apprehension over increases in risk than they did in satisfaction over decreases. Exceptions to this rule were the Occupational category for most groups and the Long-term public category for the Environmentalists and the Science Writers. Note that these two categories filled opposite roles. Occupational was the least important category for all groups; Long-term public was the most important category for the Environmentalists and Science Writers. Equality between the negative evaluation of an increase in risk and the positive evaluation of a decrease in risk thus was associated with the extremes both of indifference and of emphasis.

Judgment Process

Immediately following the 27 policy judgments, respondents completed a set of items designed to aid them in describing certain factors presumed to be central to how they made their policy judgments. The judgment process items were composed of two subsets, one of which explored the use of cutoff levels within risk categories, while the other probed the number of categories which were used. The questions about cutoff levels were introduced by the following instructions:

The alternatives in the preceding task were based on three levels of risk in each of three categories. This section deals with how you used the levels in each of the risk categories in forming your judgments. There are three possible general strategies that you could have used:

1. When you saw that an alternative included a particular risk level, you might have considered that as sufficient grounds by itself to judge the alternative as unacceptable.
2. When you saw that an alternative included a particular risk level, you might have considered that as sufficient grounds by itself to judge the alternative as acceptable.
3. When you saw that an alternative included a particular risk level, you might have taken into account the other risk levels in the alternative before arriving at your judgment.

PLEASE INDICATE THE GENERAL STRATEGY YOU RECALL USING FOR EACH OF THE NINE RISK LEVELS BY CIRCLING THE APPROPRIATE NUMBER.

For each of the the nine risk category-level combinations, respondents circled one of three numbers: 1) Sufficient grounds to reject; 2) Sufficient grounds to accept; or 3) Not sufficient grounds to accept or reject.

The second subset of judgment process items consisted of questions regarding the number and identity of the risk categories on which respondents focused in making their policy judgments. The items asked respondents whether they:

- 1) Focused primarily on a single "most important" category. If so, which one? (Short-term public, Long-term public or Occupational)
- 2) Focused on several different categories, although not necessarily of equal importance. If so, which ones? (Short term and Long-term public, Short-term public and Occupational, Long-term public and Occupational or Short-term and Long-term public and Occupational)
- 3) Did neither of the above. (Responses subsequently coded as Reject all alternatives, Accept all alternatives or Complex process.)

Results

Respondents' reported use of cutoff levels within risk categories is displayed in Figures 9, 10 and 11. Figure 9 presents the percentages of respondents who reported accepting alternative nuclear waste disposal systems based on single risk category-level combinations. As would be expected, overall reported acceptance within each risk category decreased as risk level increased. Within the "less risk" level, reported acceptance was lower for Occupational risk than for the other two categories, while the number of respondents basing acceptance on Long-term public risk was lower than for the other two risk categories within the "same risk" level. Differences among groups in reported acceptance tended to be small and inconsistent.

Figure 10 presents the percentage of respondents who reported rejecting policy alternatives based on single risk category-level combinations. Reported rejection increased with risk level within each category. Reported rejection rates within the "same risk" level were highest for Long-term public, followed by Short-term public and then Occupational. Within the "more risk" level, Occupational risk had a much lower reported rejection rate than the other two categories, which were approximately equal. Group differences were greater and more consistent for rejection than for acceptance. Within the "less risk" level, the Chemical and Nuclear Engineers were consistently lower than the other groups, indicating low levels of "protest" rejections. The Environmentalists expressed their displeasure with current nuclear waste policy through their very high reported rejection rates within the "same risk" level. Also within the "same risk" level, the Chemical and Nuclear

Figure 9. Percentages of respondents who reported accepting alternative nuclear waste disposal systems based on single risk category-level combinations, by group.

Figure 10. Percentage of respondents who reported rejecting alternative nuclear waste disposal systems based on single risk category-level combinations, by group.

General Communities	Science Writers
Hazardous Facility Communities	Environmentalists
Chemical Engineers	Nuclear Engineers
Average Importance Rating

Figure 11. Percentages of respondents who reported that single risk category-level combinations were not sufficient grounds for the acceptance or rejection of alternative nuclear waste disposal systems, by group.

- - - - - General Communities
 - - - - - Hazardous Facility Communities
 Chemical Engineers
 _____ Average Importance Rating
 - . - . - Science Writers
 + + + + + Environmentalists
 _____ Nuclear Engineers

Engineers and the Hazardous Facility Communities (those groups more closely connected with current technology) consistently had lower reported rejection rates than did the other groups (those less closely connected with current technology). Within the "more risk" level, the Environmentalists and the Science Writers had reported rejection rates higher than the other groups for all three risk categories. The Chemical Engineers were similar to the Environmentalists and Science Writers for Short-term and Long-term public risk, but had the lowest reported rejection rate of any group for Occupational risk.

Figure 11 displays the percentage of respondents who reported that a single risk category-level combination was not sufficient grounds for the acceptance or rejection of policy alternatives. Respondents reported that the "same risk" level was least sufficient for acceptance or rejection, followed by "less risk" and then by "more risk." Within each risk level, Occupational risk was more frequently reported to be insufficient than either of the other two categories, which were approximately equal. Within the "less risk" level, all groups but the Science Writers were consistently different on all three risk categories. The two public groups, General and Hazardous Facility Communities, had relatively low levels of reported insufficiency, while the Nuclear and Chemical Engineers were relatively high. The two groups of Engineers also had a consistently high rate of "not sufficient" responses within the "same risk" level; the Environmentalists were low for the Short-term and Long-term public categories. Finally, within the "more risk" level, the Nuclear Engineers and the Hazardous Facility Communities had consistently relatively high reported levels of insufficiency across all three risk categories; the Chemical Engineers were high only for Occupational risk.

The results of the reported use of cutoff levels within risk categories are summarized for the total group of respondents in Figure 12. The slope of the graphs indicates the impact of risk levels on respondents' judgments; the steeper the slope, the greater the impact. Thus, we see that risk levels had greater effect on reported decisions to reject than to accept. Also, within both the acceptance and rejection reports, risk levels affected both Short-term and Long-term public risk more than Occupational risk. That is, Occupational risk was a less significant factor in accept-reject judgments than were the other two categories. This result is also shown in the "insufficient" graph, where Occupational is much higher than the other categories of risk. The difference between "same risk" and "more risk" had greater impact on both reject and "insufficient" judgments than did the difference between "less risk" and "same risk." A change from "same risk" to "more risk" for any category produced large increases in reported rejections primarily at the expense of "insufficient" judgments, but also due to decreases in reported acceptances. A change from "same risk" to "less risk" for any category produced moderate increases in reported acceptances due to moderate decreases in both rejections and judgments of insufficiency.

Given these judgment process results on the reported use of cutoff levels within risk categories, we can address the question of how much convergence there was between these data and statistical descriptions of respondents' performance on the policy judgment task. In Table 6 are displayed the mean acceptability judgments for respondents who identified each of the nine risk category-level combinations as being sufficient for

Figure 12. Percentages of total group of respondents who reported that single risk category-level combinations led to the acceptance or rejection of alternative nuclear waste disposal systems or were insufficient grounds for either.

+++++ Short-term public risk
 --- Long-term public risk
 — Occupational risk

TABLE 6

Mean acceptability of risk category-level combinations
as a function of action categories

RISK CATEGORY	RISK LEVEL	ACTION CATEGORY					
		Accept		Reject		Insufficient	
		Mean	(N)	Mean	(N)	Mean	(N)
Short-term public risk	Less	4.0	(126)	2.0	(49)	3.5	(139)
	Same	4.1	(55)	1.8	(79)	3.2	(175)
	More	4.2	(23)	1.6	(229)	2.7	(59)
Long-term public risk	Less	4.0	(132)	2.0	(41)	3.6	(139)
	Same	4.2	(47)	1.8	(93)	3.3	(173)
	More	4.4	(18)	1.6	(226)	2.6	(67)
Occupational risk	Less	3.6	(99)	2.1	(42)	3.2	(170)
	Same	3.7	(63)	1.5	(53)	3.0	(192)
	More	4.1	(30)	1.8	(157)	2.8	(129)

the acceptance or rejection of policy alternatives, or as being insufficient grounds for either. If respondents' reports accurately described the process by which the overall judgments of acceptability were made, we would expect that within each risk category-level combination the mean acceptability judgment for respondents who said that they accepted policy alternatives based on a given combination would be higher than the mean acceptability judgment for respondents who said that they rejected policy alternatives base on that same combination. Further, we would expect that the mean acceptability judgment for respondents who said that a given risk category-level combination was insufficient grounds for acceptance to be intermediate between the mean acceptance and rejection judgments. Inspection of the entries in Table 6 provides unanimous support for these expectations. None of the mean judgments deviated from the predicted pattern, nor were there significant differences among groups. This result constitutes very strong support for the contention that both methods were providing accurate measures of the importance of each of the three risk categories within each of the risk criteria.

As described above, the second subset of judgment process items consisted of questions regarding the number and identity of the risk categories on which respondents focused in making their policy judgments. The first item inquired as to whether or not respondents focused primarily on a single "most important" category and, if so, which one. As Table 7 shows, as large majority of respondents (85.9%) reported not focusing on a single risk category. The accuracy of this report can be seen by glancing back at the graphs in Figure 8, which suggest use of at least two

TABLE 7

Percentage of Reported Use of a "Single Category"
Decision Rule, by Group

Decision Rule	General Communities	Hazardous Facility Communities	Environ- mentalists	Science Writers	Chemical Engineers	Nuclear Engineers	Total
Did not focus on a single risk category	79.4	73.9	93.1	96.7	93.8	97.2	85.9
Focused on Short-term public risk	11.8	10.2	1.4	0	0	2.8	5.8
Focused on Long-term public risk	5.9	12.5	5.6	0	3.1	0	6.1
Focused on Occupational risk	2.9	3.4	0	3.3	3.1	0	2.1
Number in group	68	88	72	30	32	36	326

risk categories by all groups. Nonetheless, some individuals did report using a single risk category, Short-term and Long-term public about equally, with Occupational receiving very little attention. Reported use of a single risk category differed among groups--the public groups (General and Hazardous Facility Communities) reported using a single category more often than did the others.

The second item explored the reported use of combinations of risk categories. The entries in Table 8 show that approximately one-third (32.4 percent) of those respondents who said they did not focus on a single category reported that they also did not focus on a combination of categories. We will take a closer look at these respondents later. Another third (33.4 percent) of this subset of respondents said they utilized all three risk categories, while one quarter (25.1 percent) reported focusing on Short-term and Long-term public. The few remaining respondents (9.0 percent) reported using other or unspecified combinations. There were no significant differences among groups.

The test of the consistency between these reports about category usage and the statistical descriptions of category use based upon the acceptability judgments is shown in Figure 13. These comparisons are made between the risk category use of respondents who reported use of Short-term and Long-term public risk versus respondents who reported use of those two categories plus Occupational risk. If respondents' reports were more accurate, we would expect to observe greater use of the Occupational category by the three-category groups and, conversely, greater use of the Short-term and Long-term public categories by the two-category group. The graphs in Figure 13 confirm these expectations.

TABLE 8

Percentage of Use of a "Multiple Category"
Decision Rule, by Group

Decision Rule	General Communities	Hazardous Facility Communities	Environ- mentalists	Science Writers	Chemical Engineers	Nuclear Engineers	Total
Did not focus on a combination of risk categories	27.6	24.2	44.1	40.0	22.6	35.3	32.4
Focused on Short-term public and Long-term public	25.0	28.8	20.6	20.0	25.8	29.4	25.1
Focused on Short-term public and Occupational	10.3	10.5	0	3.3	0	2.9	5.2
Focused on Long-term public and Occupational	6.9	3.0	1.5	0	3.2	0	2.8
Focused on Short-term public, Long-term public and Occupational	25.9	31.8	33.8	36.7	48.4	32.4	33.4
Focused on an unspecified combination	3.4	1.5	0	0	0	0	1.0
N	58	66	68	30	31	34	287
% of Group N	85.3	75.0	94.4	100.0	96.9	94.4	88.0

$$\chi^2_{(25)} = 34.0, p > 0.10$$

N = respondents who did not focus on a single risk category

Figure 13. Comparisons between the risk category use of respondents who reported use of Short-term public and Long-term public risk versus respondents who reported use of those two categories plus Occupational risk.

——— Short-term public and Long-term public (N=67)
 - - - - Short-term public and Long-term public and Occupational (N=92)

The slope of the acceptance graph for the three-category group is greater (indicates greater use) than that for the two-category group for Occupational risk. An analysis of variance (ANOVA) indicates that the two groups differed significantly on the "more risk" level of Occupational ($F = 7.17, p < 0.01$). The slopes of the acceptance graphs for the two-category group are greater than those for the three-category group for Short-term and Long-term public risk. The two groups differed significantly on the "less risk" level of Long-term public ($F = 5.87, p < 0.02$) but not quite on the "less risk" level of Short-term public ($F = 1.96, p = 0.16$).

The third item investigated respondents' reported use of judgment procedures focusing neither on single categories nor on combinations of categories. As the entries in Table 9 show, approximately three-quarters (74.4%) of those respondents who reported using neither a single-category nor a combination of categories reported using some sort of "complex process" (a procedure given or written description in their own words). Slightly fewer than one quarter (23.3%) of this subset of respondents indicated that their policy was to reject all alternatives, while the small number of remaining respondents (2.3%) reported the opposite policy of total acceptance. There were significant differences among the groups, with a large proportion (55%) of the rejectors coming from the Environmentalists and none from either group of engineers. The two respondents who adopted the accept all policy were Nuclear Engineers.

The data shown in Figure 14 provide a test for the consistency between these self-reports and the data from the acceptability judgments. Comparisons are made between the risk category use of

TABLE 9
Percentage of Use of Decision Rules, by Group

Decision Rule	General Communities	Hazardous Facility Communities	Environ- mentalists	Science Writers	Chemical Engineers	Nuclear Engineers	Total
Reject All	28.6	16.7	37.9	25.0	0	0	23.3
Accept All	0	0	0	0	0	16.7	2.3
Complex Process	71.4	83.3	62.1	75.0	100.0	83.3	74.4
N	14	12	29	12	7	12	86
% of Group N	20.6	13.6	40.3	40.0	21.9	33.3	26.4

$$\chi^2_{(10)} = 21.3, p < 0.05$$

N = Respondents who did not focus on a "single category" or a "multiple category" decision rule.

Figure 14. Comparisons between the risk category use of respondents who reported use of a "reject all" judgment process versus respondents who reported use of a "complex process."

Reject All (N=19)
Complex Process (N=61)

respondents who reported use of a "reject all" judgment process versus respondents who reported use of a "complex process." If respondents' reports were accurate, we would expect to see greater use of all three categories by the "complex process" group. The graphs in Figure 13 clearly support these expectations with significant differences between groups for all levels of all categories. Appropriately, the differences between groups were largest for the less-risk level (STP: $F = 57.74$, $p < 0.001$; LTP: $F = 34.39$, $p < 0.001$; OCC: $F = 52.40$, $p < 0.001$), moderately large for the "same risk" level (STP: $F = 38.69$, $p < 0.001$; LTP: $F = 34.39$, $p < 0.001$; OCC: $F = 40.91$, $p < 0.001$) and smallest for the "more risk" level (STP: $F = 9.81$, $p < 0.003$; LTP: $F = 7.79$, $p < 0.007$; OCC: $F = 14.24$, $p < 0.001$). Interestingly, the "complex process" group (heavily--28.1%--Environmentalists) appears to have used all three risk categories, Long-term public a bit more than Short-term public and that a bit more than Occupational. Also, in contrast to other groups which generally weighted an increase in risk more heavily than a decrease in risk, the "complex process" group weighted an increase in risk equally with a decrease for all three risk categories.

Taken together, the results on the accuracy of respondents' self-reports on category utilization provide very strong and substantial support for the ability of respondents to rate the hypothetical waste management systems in a reliable manner and to provide an accurate report about the judgment processes they used.

Summary

A multiple-attribute judgment task was used to investigate the relative importance respondents placed on three categories of risk. Respondents judged the acceptability of alternative nuclear waste disposal systems based on levels of risk (significantly less, same, or significantly more than the current system) in three risk categories, Short-term public, Long-term public and Occupational. Results showed that Occupational risk was less important than the other two categories for all groups of respondents, especially for the Chemical and Nuclear Engineers. For most groups, Short-term public risk was approximately as important as Long-term public risk. For the Environmentalists and Science Writers, however, Long-term public was slightly more important than Short-term public. With some exceptions, increases in risk effected greater changes in acceptability than did decreases. Increases and decreases in risk level were equally weighted in the Occupational risk category by all groups (this was consistently the least important risk category). Similar evidence of equal weighting was found in the Long-term public category by Environmentalists and Science Writers (this was their most important category). The results on the relative importance of the three risk categories will be compared with similar results from a different task in the Conclusions section of this report.

Following the policy judgment task, respondents completed a set of items inquiring about the processes they had used. Items in this section were based on the earlier work of Weitz and Wright (1979) and reflected their notion that "the accuracy of retrospective reports is...partly dependent on whether the probe uses language that enables a subject to

directly and unambiguously retrieve the appropriate memory, and on whether the events probed are those the person would have naturally attended to at the time." The present study was successful in finding correspondence between retrospective reports and specific aspects of respondents' judgment processes. The results showed that respondents were able to effectively use the complex judgment task to express their preferences for alternative waste management systems. The data also show that respondents are able to accurately report their use both of cutoff levels within risk categories and their overall relative use of the three categories of risk. These results are consistent with those of Maynard, et al. (1976) who found convergence among a number of measures of the relative importance of different evaluation criteria. These data also support the arguments of Weitz and Wright (1979) that people are capable of accurate self-insight, given an appropriate task and appropriate inquiries regarding their behavior in that task. The present study is the first to examine the self-insight of large samples of "ordinary" people, and the results raise questions about the generality of the position espoused by Nisbett and his colleagues (Nisbett and Bellows, 1977; Nisbett and Wilson, 1977a, 1977b), viz. that people are not capable of accurate self-insight.

HUMAN VALUE DIFFERENCES AMONG GROUPS

Introduction

Recently, there has been growing awareness that the attitudes and beliefs that individuals have regarding environmentalism and various energy technologies are related to the individual's basic value positions. Human values, including a world of beauty, family security, national security, and freedom have been studied regarding recycling behavior (Dunlap, Grineeks, and Rokeach, 1981), the electric power industry (Maher, 1977), nuclear power and nuclear waste management (Maynard, et al., 1976; Hébert, et al., 1978; Rankin and Nealey, 1978), and energy technologies, more generally (Rankin, 1981). The work by Dunlap, et al., (1981) and by Rankin (Rankin and Nealey, 1978; Rankin, 1981) have found the human value concept as defined by Rokeach (1968; 1973) to be useful in analyzing the underlying reasons for why people think and behave the way that they do regarding conservation and various energy technologies, especially nuclear power. A variant of the Rokeach value measurement technique was used in this analysis.

For our purposes, a value is defined as a belief that a state of existence is personally or socially preferable to the opposite state of existence. Rankin and Nealey (1978) and Rankin (1981) found that eight values were related to beliefs and attitudes about energy technologies, especially nuclear power. These values were used in this research and included: a comfortable life, a world at peace, a world of beauty, equality, family security, freedom, inner harmony, and national security.

Because of the risk perception tasks in the questionnaire, the values for an exciting life and future security were also included. Finally, the value for justice was also included.

Similarities among Groups on Value Importance

Respondents were asked to rate each of the eleven values from 1 (most important) to 7 (least important) according to the importance that the value had in guiding the person's thoughts and behaviors. A comparison of the six respondent groups on importance of the eleven values is presented in Table 10. In the table, the average importance rating is presented for each group for each value. The values were then rank ordered according to average importance ratings within each group, and these rank orderings are presented in parentheses in the table.

According to Rokeach's (1968; 1973) theory of human values, one individual (group) does not have more "values" than another individual (group). Rather, what differs among groups is the ordering of importance of the values. For example, an environmentalist and an Army officer might place the same importance on the value of a world of beauty. However, if the environmentalist believes that national security is less important than a world of beauty and the officer believes the converse, then the two individuals are likely to have different attitudes toward the acceptability of siting a facility related to national security, such as a military base. Thus, the following discussion will emphasize a comparison of the rank orderings of the values. This task was contained in both questionnaires, and the respondents therefore were those of Set #3.

TABLE 10

Average Importance of Human Values as a Function
of Respondent Groups

Human Value	General Communities	Hazardous Facility Communities	Environ- mentalists	Science Writers	Chemical Engineers	Nuclear Engineers	p ^b
A comfortable life	3.54 (9) ^a	3.43 (10)	4.73 (11)	4.52 (11)	4.03 (10)	3.84 (11)	.001
An exciting life	3.76 (11)	4.06 (11)	3.82 (10)	3.45 (10)	3.94 (9)	3.54 (8)	ns
A world at peace	2.07 (2)	1.95 (3)	1.91 (1)	2.00 (1)	3.75 (6)	2.73 (3)	.001
A world of beauty	3.65 (10)	2.67 (7)	2.47 (5)	2.49 (4)	3.90 (8)	3.66 (9)	.001
Equality	2.66 (7)	2.89 (9)	2.66 (7)	2.73 (6)	3.77 (7)	3.32 (7)	.001
Family security	2.22 (3)	1.88 (2)	2.54 (6)	2.60 (5)	2.37 (2)	2.18 (1)	.001
Freedom	1.98 (1)	1.87 (1)	2.27 (2)	2.16 (2)	2.14 (1)	2.38 (2)	.01
Future security	2.37 (5)	2.34 (6)	2.37 (4)	2.88 (7)	3.24 (5)	3.27 (6)	.001
Inner harmony	2.70 (8)	2.75 (8)	3.31 (9)	3.36 (9)	4.24 (11)	3.67 (10)	.001
Justice	2.26 (4)	2.12 (5)	2.32 (3)	2.45 (3)	3.22 (4)	3.05 (5)	.001
National security	2.42 (6)	1.99 (4)	3.25 (8)	3.00 (8)	2.56 (3)	2.77 (4)	.001

NOTE: "For each of the values listed below, circle one number to give us your opinion on the importance to YOU of these values compared to each other in guiding YOUR thoughts and behavior." The ratings ranged from much more important (1) to much less important (7).

^aRank order of human values from most important (1) to least important (11) is presented in parentheses.

^bThe probability that the differences between group means on value importance are due to chance alone as determined by analysis of variance.

Looking at Table 10, it is apparent that three pairs of the respondent groups have highly similar values systems. First, the value systems of the General Communities and the Hazardous Facility Communities are much alike. Eight of the values are ranked the same or differ only by one rank between groups, and national security and equality differ by two ranks. The largest difference is for a world of beauty, which differs by three rank orders. The Hazardous Facility Communities place more importance on a world of beauty than do the General Communities.

The value systems of the Science Writers and the Environmentalists are also quite similar. Seven of the eleven values have exactly the same ranking, and three of the remaining four values differ only by one rank. The major difference is on future security, which Environmentalists believe to be more important than the Science Writers by a difference of three ranks.

Finally, the value systems of the Chemical Engineers and the Nuclear Engineers are quite alike. Ten of the eleven values differ by one rank or less. The eleventh value, a world at peace, is believed to be more important by the Nuclear Engineers than by the Chemical Engineers by a difference of three ranks.

Differences among Groups on Value Importance

The major value importance differences were among the three pairs of respondent groups described above. These differences, which are discussed below, involve the values: a world at peace, a world of beauty, family security, and national security.

Environmentalists and Science Writers ranked a world at peace as the most important value. The General and Hazardous Facility Communities ranked a world at peace as second or third in importance, while the Nuclear and Chemical Engineers ranked a world at peace, respectively, as third and sixth in importance. This difference is consistent with that found by Rankin and Nealey (1978) and supports their hypothesis that Environmentalists are much more likely to cite proliferation concerns regarding nuclear power expansion than other groups because of the importance that they place on a world at peace.

The second major difference in value rankings is with regard to a world of beauty. Since this value is closely related to the environmental movement, it was expected that the Environmentalists would place more importance on this value than most other respondent groups. Environmentalists and Science Writers ranked a world of beauty fourth or fifth in importance, while the four remaining groups ranked it seventh through tenth in importance.

The third major value difference among groups is with regard to family security. Family security was ranked first or second in importance by the Chemical and Nuclear Engineers and second or third in importance by the General and Hazardous Facility Communities. However, less importance was placed on this value by the Science Writers and Environmentalists, who ranked it as fifth or sixth in importance. A related finding here is with regard to the relative rankings of the importance for family security and future security. Environmentalists ranked future security as more important than family security, whereas the opposite was the case for the other five respondent groups. This

finding should be compared with results presented earlier in this report, which showed that Long-term public risk and Short-term public risk were of equal importance to all groups for making acceptability judgments, except Science Writers and Environmentalists, who placed more importance on Long-term public risk. The value findings indicate that when Short-term public risk is defined more narrowly as risk to one's own family, (family security) then all groups except Environmentalists place significantly more importance on risk to family than on risk to future generations (where risk to future generations is closely analogous to Long-term public risk). This indicates that risk to future generations is a much more important issue to Environmentalists than to the other groups involved in issues regarding nuclear waste management.

The final major difference is with regard to national security. The Science Writers and Environmentalists placed much less importance on this value (both groups ranked it eighth in importance) than did the four remaining groups, who ranked national security third, fourth, or sixth in importance. This is another reason why proliferation concerns may be more salient to Environmentalists with regard to nuclear waste management issues.

Summary and Discussion

Some of the respondent groups had value systems that were very much alike. Specifically, the General Communities and the Hazardous Facility Communities were much alike in value importance rankings, as were the Science Writers and Environmentalists and as were the Chemical Engineers and Nuclear Engineers. The few exceptions to this generalization were

that the Hazardous Facility Communities placed more importance on a world of beauty than did the General Communities; the Environmentalists placed more importance on future security than did the Science Writers; and the Nuclear Engineers placed more importance on a world at peace than did the Chemical Engineers.

The major differences in value importance were among the pairs of groups. The Science Writers and Environmentalists placed more importance both on a world at peace and on a world of beauty than did the other four groups. However, the Science Writers and Environmentalists placed less importance both on family security and on national security than did the other four groups. A final important difference is that Environmentalists ranked future security as more important than family security, while just the opposite was the case for the other five respondent groups.

Although other respondent groups were analyzed by Dunlap, et al., (1981) and by Rankin (Rankin and Nealey, 1978; Rankin, 1981), the findings discussed above were consistent with the findings of these researchers. The importance of this consistency is related to the fact that the researchers have found that certain human values serve as an underlying basis for individual thoughts (beliefs and attitudes) and behaviors regarding energy technologies. The implication, then, is that these same values also help to determine an individual's perception of the risks related to the hazardous facilities that were used in this study, especially since most of the hazardous facilities are energy-related. However, as discussed by Rankin (1978), the values do not totally explain why an individual thinks or acts in a given manner with regard to energy

facilities. That is, specific thoughts and behaviors are also determined by other factors, such as peer group influence, group membership in activist or professional organizations, and knowledge about the energy technologies.

Thus, data discussed above suggest that the respondent groups will perceive the risks of hazardous facilities differently. More specifically, Nuclear Engineers and Chemical Engineers are likely to perceive risks in somewhat the same manner and are likely to perceive hazardous facilities as less risky than other respondent groups. Additionally, the General Communities and Hazardous Facility Communities are likely to perceive risks in somewhat the same manner, and are more likely to believe that the hazardous facilities are more risky than do the two Engineer groups. However, differences in the two Communities groups regarding experience with hazardous facilities and regarding the difference in the importance placed on a world of beauty suggest that these groups will not have identical risk perceptions. Finally, the value findings suggest that Science Writers and Environmentalists may perceive risks in somewhat the same manner, and that they may perceive the hazardous facilities as more risky than the other respondent groups. However, differences in vocation, peer group influence (e.g., Environmentalists belong to groups that often oppose energy facilities for environmental reasons), and the importance placed on future security by the Environmentalists suggest that the risk perceptions of Environmentalists and Science Writers will not totally overlap.

CONCLUSIONS

The study of synthetic measures of public perception of the risk associated with nuclear wastes produced results with significance for the study of risk perception in general. First, it was demonstrated that risk perception could be usefully studied through its constituent parts. Judgments of probabilities and consequences were combined to generate synthetic risk perception measures. Those measures were used to successfully predict judgments of the acceptability of nuclear power. When the synthetic risk perception scale was added to global measures of risk and benefit, little difference in the degree of predictability resulted. This indicated that the synthetic and global measures contained similar information. The combination of risk and benefit measures accounted for a large percentage of the variance in the acceptability judgment, indicating that other factors may have little independent effect. In interpreting this finding, it must be kept in mind that both risks and benefits were subjectively defined. Thus, risks and benefits, as categories, may function broadly as pluses and minuses, providing respondents with a means of dividing the world simply into the good and the bad. Further studies comparing synthetic with global measures of both risk and benefit are required in order to explore this question.

A second area of general significance involves the results relating judgments of likelihood, recall and tragedy. The primary implication was that respondents' judgments of the likelihood of significantly bad effects due to nuclear wastes were the products of a variety of processes and

could be accounted for only in part by frequency (recall) and salience (tragedy) information. As an example of the various judgment processes, the Nuclear Engineers can be compared with the Science Writers. For the Nuclear Engineers, likelihood was consistently unrelated to both recall and tragedy. This result may have been due to a restriction in the range of possible judgments imposed on the respondents by the likelihood scale. Thus, for example, the likelihood judgments of Nuclear Engineers may be highly related to recall and/or tragedy for some hazards unrelated to nuclear wastes. There may be no general absence of relations between likelihood, recall and tragedy for the Nuclear Engineers. The judgments by those respondents of the likelihood of bad effects due to nuclear wastes were, however, almost uniformly at the low end of the scale and, therefore, unrelated to judgments of recall and tragedy. It seems likely that Nuclear Engineers drew on their personal familiarity with the calculated probabilities in making those judgments.

In contrast, the Science Writers consistently related likelihood to recall but not to tragedy. This result appears to be a product of the Science Writers' role in our society. As professional communicators of relatively objective information, the Science Writers would be expected more than the other groups to produce likelihood estimates related to recall judgments. This expectation can be understood through an application of the availability heuristic (Tversky and Kahneman, 1973). Persons required to make likelihood judgments may be influenced by the relative availability of the events. Availability refers to the ease with which the events can be accessed by cognitive processes, and it can be affected by frequency of the events but also by such qualitative factors as

salience and vividness. To the extent that availability is actually associated with event frequency, the heuristic can be useful. Otherwise, it can lead to errors in judgment. On the assumption that Science Writers are trained to be aware of the factors affecting their judgments, their likelihood estimates would be expected to be consistently related to recall (frequency) and not to tragedy (salience).

The study of synthetic measures of public risk perception demonstrated that those measures could account for a maximum of 67% of the variance in respondents' judgments of the acceptability of nuclear power. Risk was thus the most important factor affecting acceptability. The risk measure used in those calculations, however, included separate measures referring to three groups of persons: 1) Short-term public, 2) Long-term public, and 3) Occupational. The question, then, is whether these three categories of risk have differing impacts on acceptability. The multiple-attribute judgment task designed to provide an answer to this question generated statistical descriptions of respondent's judgments of the acceptability of hypothetical nuclear waste disposal systems.

In an investigation of respondents' judgment processes, the statistical descriptions were found to be very similar to respondents' self-reports. Previous studies, such as that of Weitz and Wright (1979) have used statistical descriptions as baselines against which to assess the accuracy of respondent self-reports. Accurate self-reports were assumed to be evidence for accurate self-insight. There is no reason to believe, however, that statistical descriptions are in any useful sense accurate renderings of respondents' judgment processes. Rather than

judge the accuracy of self-reports relative to statistical descriptions, a more valid approach is to treat each of the measurement techniques as an alternative way of viewing the judgment processes. Strong correspondence between the results of the two techniques would then generate confidence that those results were valid. And it follows from this that respondents' self-reports would be considered to be accurate. Since there was strong correspondence in this study, we can conclude that respondents demonstrated accurate self-insight. This result raises questions about the generality of the position espoused by Nisbett and his colleagues (Nisbett and Bellows, 1977; Nisbett and Wilson, 1977a, 1977b), viz., that people are not capable of accurate self-insight.

The statistical descriptions of respondents' judgment processes indicated that Occupational risk was less important than the other two categories for all groups of respondents, especially for Chemical and Nuclear Engineers. For most groups, Short-term public was slightly less important than Long-term public. The difference in importance between Short-term and Long-term risk was most noticeable for Environmentalists and Science Writers. These data are quite consistent with the hypothesis that the acceptability of risk is a function of its voluntariness. They follow the pattern that would be predicted from Starr's (1969) revealed preference data and from the Maynard, et al. (1976) expressed preference data (see Fischhoff, et al. 1978, for a discussion of this issue).

Since the present data are drawn from a large sample of respondents that differ on many demographic characteristics, one can conclude that these results generalize across persons. That the results for short term and long term risk are consistent with those reported by Maynard, et al.,

(1976) suggests that there is some generalizability over time. However, there is another facet of generalizability that must be considered, generalizability over methods of measurement.

Earle (1981) used a free-response approach to the measurement of the relative salience of the three categories of risk. Respondents were asked, "In your opinion, what persons would be placed at risk by a nuclear waste disposal facility?" Results indicated that Short-term public risk was mentioned three times as often, and Occupational risk two times as often, as Long-term public risk. As pointed out in Earle (1981), the apparent conflict between these free-response results and the present fixed-response results can be readily resolved by a careful examination of the two tasks. In brief, the free-response task elicited respondents' concerns about which groups of persons would experience significant adverse effects. Results in the fixed response task, on the other hand, were based on respondents' judgments of equity: how should risk be distributed over the given groups of persons? Respondents indicated that persons in the Occupational category should bear more risk than others, presumably on the basis that workers volunteer to expose themselves to risks and are paid to do so. This comparison between these two sets of results underscores the importance of the use of a variety of methods in the study of risk perception. Methods inevitably affect results, and those effects can only be understood through comparisons among diverse methods.

In the final study contained in this report, it was argued that differences in values among respondent groups may cause differences in risk perception. Specifically, it was suggested that Nuclear Engineers

and Chemical Engineers would be similar in their perceived risks, General Communities and Hazardous Facility Communities would be similar and Science Writers and Environmentalists would be similar. In addition, the magnitude of the perceived risk would be smallest for the Engineers and largest for the Science Writers and Environmentalists. These rough speculations were tempered by caution that many factors other than values affect risk perception. A test of these projected relations between values and risk perception is available in the form of a comparison with the synthetic risk judgment generated in the first study in this report. Synthetic risk judgments were calculated for three categories of risk, Short-term public, Long-term public and Occupational. The order of groups in magnitude of perceived risk from a Nuclear Waste Disposal Facility was identical within each category: Nuclear Engineers (lowest), Chemical Engineers, Science Writers, Hazardous Facility Communities, General Communities, and Environmentalists (highest).

The comparison between group differences predicted on the basis of values and those produced by the synthetic risk judgment is both supportive and instructive. The two sets of data are similar enough to indicate some form of general relationship. For example, the Nuclear and Chemical Engineers had like values as well as like risk perceptions, and such was also the case for the two community groups. The relationship, however, is clearly complex and mediated by many additional factors. (See Hughes, et al., 1976, for a study of the relations between values and decisions.) For example, the perceived risk of a nuclear waste facility obtained for the Nuclear Engineers was lower than that obtained for the Chemical Engineers. Results from related studies reported in

Lindell and Earle (1981) suggest that a key factor is the specific type of industrial facility. Nuclear Engineers tended to judge nuclear related facilities less risky than certain other hazardous facilities. Chemical Engineers, on the other hand, made little distinction among facilities. A second example of the complexity inherent in risk perception involves the Science Writers. According to the values study, their level of perceived risk should be close to that of the Environmentalists; instead, they are very much lower. As was shown in the first study in this report, the Science Writers had lower levels of perceived risk than the Environmentalists because they had lower judgments of the likelihood of significantly bad effects due to nuclear wastes. The likelihood judgments of the Science Writers were much closer to those of the Engineers than were those of the Environmentalists. The Science Writers were closer, then, to persons familiar with the calculated risks associated with nuclear wastes. It can be inferred from this that the Science Writers were more knowledgeable and open to the influence of calculated risks. Knowledge and respect for scientific evidence thus seems to have intervened in this case between values and perceived risk for the Science Writers.

Values, by definition, are very general. Risk perception, according to the available evidence, can be very specific--dependent on the object and the situation in which it is judged. Values can thus serve as a general guide to risk perception, but knowledge of public risk perception at any specific level appears dependent on well-designed studies capable of dealing with the complexity and variability of human cognitive processes.

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