Risk Analysis, in press.

POWERLINE FREQUENCY ELECTRIC AND MAGNETIC FIELDS:
A pilot study of risk perception

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Perception of the potential risk arising from human exposure to 50/60 Hz electric and magnetic fields was studied with a quasi-random sample of 116 well educated opinion leaders using the risk perception framework previously developed by Slovic, Fischhoff and Lichtenstein. These individuals rated exposure to fields from transmission lines and electric blankets on a variety of scales that have been found useful in characterizing people's risk attitudes and perceptions. These judgments allowed us to conjecture about the likely desire for regulation of these potential hazards and the likely response to a publicized problem (e.g., an accident or ominous research finding) involving these two sources of exposure. Various forms of detailed information about 50/60 Hz fields were supplied to respondents. Provision of information produced modest, but statistically significant changes in perceptions, in the direction of greatest concern about the risks. In response to questions of public policy, subjects desired modest regulatory control of field exposure from transmission lines and little or no control of field exposure from appliances like electric blankets.

Key Words: Risk perception, health effects, electric fields, magnetic fields, electromagnetic fields, 60 Hz power lines.

1. INTRODUCTION

Despite the absence of persuasive scientific evidence, the idea that low frequency electric and magnetic fields may interact with and cause effects upon living systems has flickered on and off in the public and scientific consciousness for roughly two hundred years. In the late 1960's a series of studies in the Soviet Union of people occupationally exposed to powerline frequency (i.e., 50/60 Hz) electromagnetic fields reported a variety of non-specific complaints (1). These studies, which, were highly subjective in nature, prompted a number of studies in the West (2). Much of this early work suffered from problems in experimental design and execution arising from resource constraints and from the interdisciplinary nature of the field. More recently, well funded on-going research programs have been supported by the U.S. Navy, the U.S. Department of Energy and the Electric Power Research Institute (3). Additional support has been available from other public and private agencies.

As a result of this and other work it is now clearly established that at least under some circumstances 50/60 Hz electromagnetic fields can interact with and produce

effects in living systems. This is not to say that such effects can in turn give rise to significant health consequences. Indeed, at this point there is no definitive evidence of significant health consequences, and there is a very large volume of negative experimental findings.

While a sound scientific understanding of exposure processes and effects processes is essential to adequate risk assessment and management, it does not constitute the whole story. Equally important are the processes by which people perceive and make judgments about known or suspected hazards (4,5). Thus, when we recently undertook an analysis of the risk assessment needs and opportunities in this field (6,7) for the U.S.Department of Energy (DOE), we placed considerable emphasis on performing a pilot study of risk perception. This paper reports findings from that work.

2. FACTOR ANALYSIS STUDY OF RISK ATTRIBUTES

Whereas many risk experts think of risk as being largely or entirely captured by an expectation value on mortality or morbidity, lay people tend to consider a variety of other attributes when they judge the riskiness of a known or potential hazard. This has been illustrated in a series of experiments conducted by Slovic, Fischhoff, Lichtenstein and their colleagues in which subjects were asked to evaluate hazards in terms of a number of seven point scales over risk attributes or characteristics which had been hypothesized in the literature to influence people's perceptions of risk (4,8,9).

In these studies, three groups of attributes displayed a high degree of inter-attribute correlation, with low correlation across the groups. A factor analysis was performed from which a three dimensional solution emerged with factors made up of groups of attributes which can be broadly described as "dread", "familiarity" and number of persons exposed. These findings have now been replicated a number of times with a variety of experimental designs and groups of subjects and appear to be quite robust.

Other studies (10,11) have demonstrated that the location that a hazard occupies in this space is strongly correlated with people's attitude toward the degree of regulation they feel is necessary. Location in the space also correlates with the extent to which people see mishaps or problems involving a hazard as "signals" indicating that risk management systems may not be functioning and that the hazard is more serious than previously believed.

In our pilot study of risk perception of 50/60 Hz electromagnetic fields, we chose to use this body of previous findings as a framework within which to evaluate people's perceptions of the potential hazards of exposure to 50/60 Hz fields from high voltage transmission lines and from common electric appliances such as electric blankets.

Our experimental instrument, which is reproduced and discussed at considerable length in our DOE project report (6), consisted of two parts. The first part replicated the earlier studies using a subset of nine of the risk attributes employed by Slovic et al. A set of sixteen known or potential hazards were used. Most had been previously used in one or more of the Slovic et al. studies. Figure 1 illustrates the form in which subjects were asked to evaluate each of these 16 hazards against one of the risk attributes, immediacy of effect. Subjects completed similar pages for each of the eight other attributes. In addition, we asked subjects for their views about the adequacy of existing control of possible risk from each of the sixteen items (hazards). We also asked them how sure they were that each item (hazard) did or did not actually present a risk. While responding to all these questions, subjects were unaware that our interests was 50/60 Hz fields.

In the second part of the questionnaire, which subjects did not see until they had completed and sealed the first part in an envelope, our focus was specifically on 50/60 Hz fields. Details on questions in this part are discussed later in the paper.

1. Immediacy of Effect

To what extent do the risks from this activity, substance or technology occur immediately ...or do consequences occur only at some later time?

		consequences immediate						consequences delayed
		1	2	3	4	5	6	7
1.	Automobiles (accident risks, not air pollution, etc.)	☐	☐	☐	☐	☐	☐	☐
2.	Pesticides	☐	☐	☐	☐	☐	☐	☐
3.	Electric blankets (electric and magnetic fields, not shock or fire)	☐	☐	☐	☐	☐	☐	☐
4.	Microwave ovens (microwave radiation, not shock or fire)	☐	☐	☐	☐	☐	☐	☐
5.	Large dams	☐	☐	☐	☐	☐	☐	☐
6.	Diagnostic X-rays	☐	☐	☐	☐	☐	☐	☐
7.	Plastic food containers (absorbed chemicals)	☐	☐	☐	☐	☐	☐	☐
8.	Nuclear reactors	☐	☐	☐	☐	☐	☐	☐
9.	Caffeine	☐	☐	☐	☐	☐	☐	☐
10.	Large power lines (electric and magnetic fields, not shock or accident)	☐	☐	☐	☐	☐	☐	☐
11.	Handguns	☐	☐	☐	☐	☐	☐	☐
12.	Cigarette smoking (inhaled material not fires)	☐	☐	☐	☐	☐	☐	☐
13.	Power lawn mowers	☐	☐	☐	☐	☐	☐	☐
14.	Vjdeo display terminals (VDTs) (excluding arcade games and home TV sets)	☐	☐	☐	☐	☐	☐	☐
15.	Commercial aviation (i.e. scheduled airlines)	☐	☐	☐	☐	☐	☐	☐
16.	Bicycles	☐	☐	☐	☐	☐	☐	☐

Figure 1: Example page from part 1 of the questionnaire illustrating the form in which subjects were asked to evaluate the sixteen known or potential hazards.

Subjects in this study were 116 alumni of Carnegie-Mellon University. We chose this group because we were interested in the perceptions of well educated opinion leaders, and because our experimental design required rather more reading and complex cognitive tasks than we felt were appropriate for a random sample of U.S. adults.

Subjects were drawn randomly from the alumni rolls of several units of Carnegie-Mellon University. A total of 300 potential subjects were approached by letter. Of these, 182 indicated a willingness to participate. Questionnaires were sent to 166 of whom 111 were men, 60 held degrees in science or engineering, and 106 held degrees not in science or engineering. We received completed questionnaires from 116, or 70%, of this group. Because responses were anonymous we could not compare the statistical characteristics of the 116 respondents with those of the 166 participants.

A three factor solution of the type previously obtained (8,9) was found for the data from the first part of the questionnaire. This solution is shown in Figure 2. One might expect people to respond to possible 50/60 Hz electromagnetic field related health risks in roughly the same way they respond to other risks that are located "nearby" in the factor space. Using an euclidian measure of distance,[3] we identified the ten nearest neighbors in the 90- and 81-hazard studies previously run by Slovic et al. (9). The results are reproduced in Table 1. Note that the 81-hazard study included "high tension electric wires". This refers to an item regarding "ionizing radiation" from high voltage transmission lines which Slovic et al. erroneously included in their earlier 81-hazard study.[4]

We can use the results of Figure 2 along with the earlier results of Slovic et al. (10,11) to make an informed conjecture about how well-educated people are likely to respond to transmission line and electric blanket field exposure from the points of view of

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[3]The distance measure was $(\sum_{i=1} |d_i|^2)^{\frac{1}{2}}$ where i is an index running over the nine risk characteristics and d_i is the difference between ratings for the ith characteristic.

[4]There is no ionizing radiation from 50/60 Hz transmission or distribution lines or appliances. Further, because one is operating in the quasi-static regime, and in the near field, the exposures discussed in this paper are not properly described as involving radiation.

TABLE 1: Ten nearest neighbors to transmission line fields as computed for the earlier 90- and 81-hazard studies performed by Slovic, Fischhoff and Lichtenstein (9).

90 Hazard Study		81 Hazard Study	
Hazard	"Distance"	Hazard	"Distance"
Earth orbiting satellite	1.75	Nitrogen fertilizers	1.35
Space exploration	2.24	Polyvinyl chloride	1.68
Solar electric power	2.94	High tension lines*	1.87
Non-nuclear electric power	3.07	Cadmium usage	2.01
Fossil electric power	3.12	Airborne lead from autos	2.21
Food coloring	3.17	Chlorination of drinking water	2.30
Hydroelectric power	3.18	Trichloroethylene	2.45
Food irradiation	3.22	Nitrites	2.46
Food preservatives	3.25	Mercury	2.47
Water florination	3.29	Mirex (insecticide)	2.49

*See discussion in text and footnote 4.

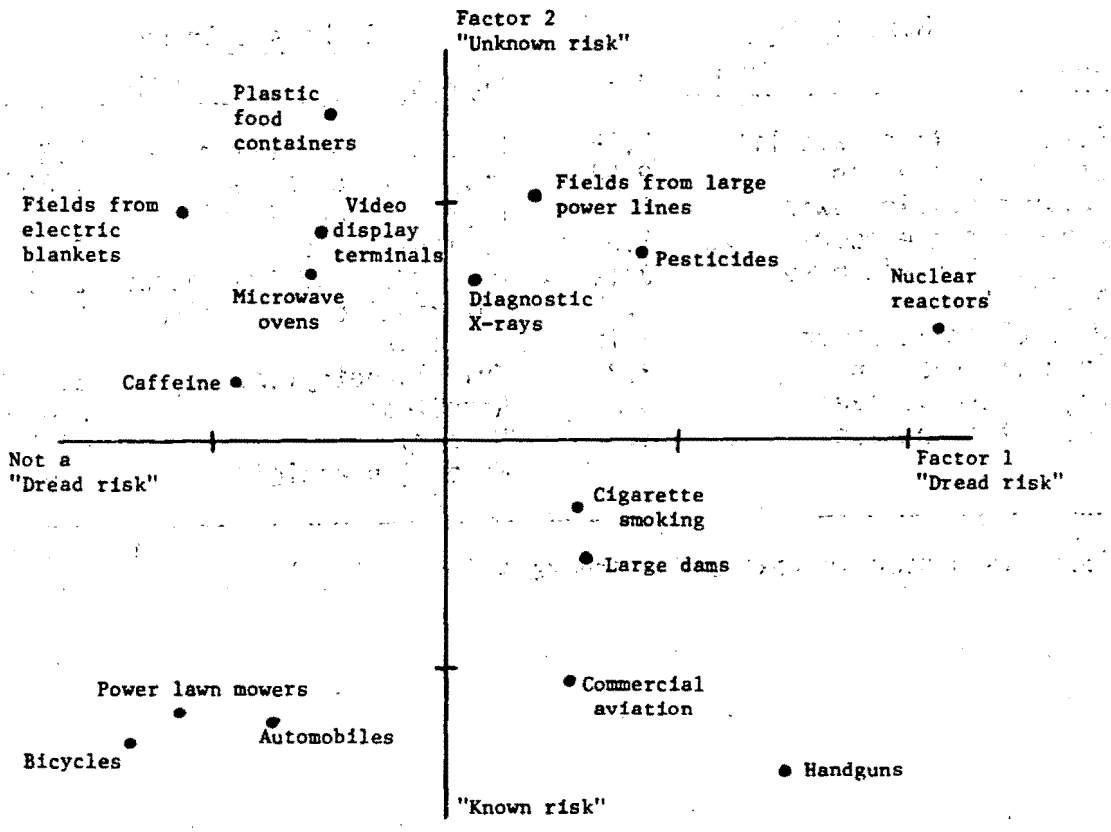


Figure 2: Result of the factor solution for the sixteen known or potential hazards addressed in Part 1 of the study. A third factor, number of persons exposed, is not shown.

regulatory involvement and "signal potential". It appears that such people are likely to want little or no regulatory response to electric blankets and a significant, but not severe, regulatory response to transmission line fields. If "events" that involve electric field health effects occur, they appear likely to be seen as having fairly high "signal potential". As a result, they will probably receive considerable media publicity and generate a great deal of concern. The indirect or higher order costs of such events are likely to be very high. Similar events involving electric blankets, and probably other electric appliances, will probably be seen as having only modest "signal potential".

At the end of the first part of the study, we supplied subjects with sixteen cards, each of which carried the name of one of the known or potential hazards. Subjects were instructed to write a 10 on the card with the lowest risk and then mark proportionally larger numbers on other cards to show how much riskier they thought the other items were. Interpretative of the results requires an understanding of the design of the second part of the study and for this reason will be discussed as part of the next section.

3. EFFECTS OF INFORMATION

In the second part of the questionnaire, we explained that we were specifically interested in powerline frequency electric and magnetic fields. We began this section by asking our subjects if they had previously heard of this topic and if so what they had heard and where. Sixty-three percent of our subjects said they had some previous knowledge. Most reported only general knowledge drawn from television coverage (both 60 Minutes and NOVA were cited), and from popular magazines. A few cited things they had seen in Science or in various publications of the Institute for Electrical and Electronics Engineers. One reported having been to a seminar on the subject. Possible effects on farm animals and on crops[5] were cited by several as specific things they had heard. Several also mentioned the irradiation of the U.S. embassy in Moscow.[6]

[5]While anecdotal stories about such effects abound, large high quality studies of cows (12), and effects on crop yields (13) have been definitively negative. There are effects on bees when field strengths in hives become large enough to give them shocks when they step from hive to hive (14).

[6]This involved microwaves at a frequency many millions of times higher than the power line frequencies of interest in this study.

In the beginning of the second part, we also ask subjects if they now lived or ever had lived near a large transmission line (there was a picture to make it clear what kind of line we were talking about). Twenty-one percent answered that they had. A somewhat larger number (35%) reported that they knew somebody who does or has lived by such a line.

We then provided subjects with detailed information on this topic. This information was supplied in three versions. Version A provided non-technical discussions of:

1. What electric and magnetic fields are.
2. What is known about possible undesirable health impacts of exposure to 60 Hz fields.
3. How the fields from transmission lines compare in strength with other 60 Hz fields. (Most of this information was supplied pictorially rather than numerically.)

The text of this version is reproduced as Appendix 1. Version B included all three items, but neglected to explicitly mention cancer or birth defects in item 2. In place of those paragraphs it vaguely remarked about the tentative nature of "various findings on other possible effects." Version C included all of item 2 on effects, but did not include item 1 on what fields are or item 3 comparing various fields to which people are exposed.

After providing this background information subjects were asked a variety of questions on appropriate regulatory responses, willingness to pay for exposure control, the importance of alternative mechanisms for causing health effects, the motivation of interveners, and the relative importance of various factors in transmission line siting. Part 2 closed by asking the subjects to again complete the questions of Part 1 for the two specific cases of transmission line fields and electric blankets.

Now that the design of Part 2 of the study has been explained, we can describe the results of the card sorting exercise in which subjects ranked and quantitatively evaluated the riskiness of the sixteen hazards or potential hazards at the end of Part 1.

The quantitative evaluation asked subjects to indicate how many times more risky the hazard was than the least risky hazard. These rankings and evaluations were performed before subjects learned the focus of our interest and before receiving any specific information on 60 Hz fields. The rankings obtained (where 1 is the least risky) are displayed in Figure 3 for all of respondents (above) and for the three groups which would later constitute the various information treatment classes. Judgments of how much riskier an item is than the least risky item, are displayed for the full set of respondents in Figure 4. Means for the distributions of the groups that would later become the three information treatment groups are also reported. A single data point from group C, in which the respondent indicated that he or she viewed transmission lines as 9000 times more risky than the least risky item, has been excluded.

We draw three important conclusions from these data. First, our subjects viewed exposure to electric and magnetic fields from both large transmission lines and electric blankets as among the least risky of the sixteen known and potential hazards they considered. Indeed, 48% placed electric blankets as the least risky and 19% placed transmission lines as the least risky of the hazards. Second, our subjects placed transmission lines as slightly more risky than electric blankets. Finally, before supplying them with any information, subjects in group A viewed transmission lines as significantly less risky than did subjects in groups B and C. This variability presumably results from the relatively small numbers of subjects (A:37, B:40, C:39) in the three groups. It does not seem to be explained by the proportion of respondents in each group that had previously heard about the fields/health effects topic (A;65%, B:55%, C:69%). This finding suggests that results obtained by information treatment class in Part 2 should be interpreted with great care. To the extent these results have meaning it is primarily in terms of relative shifts and not absolute levels.

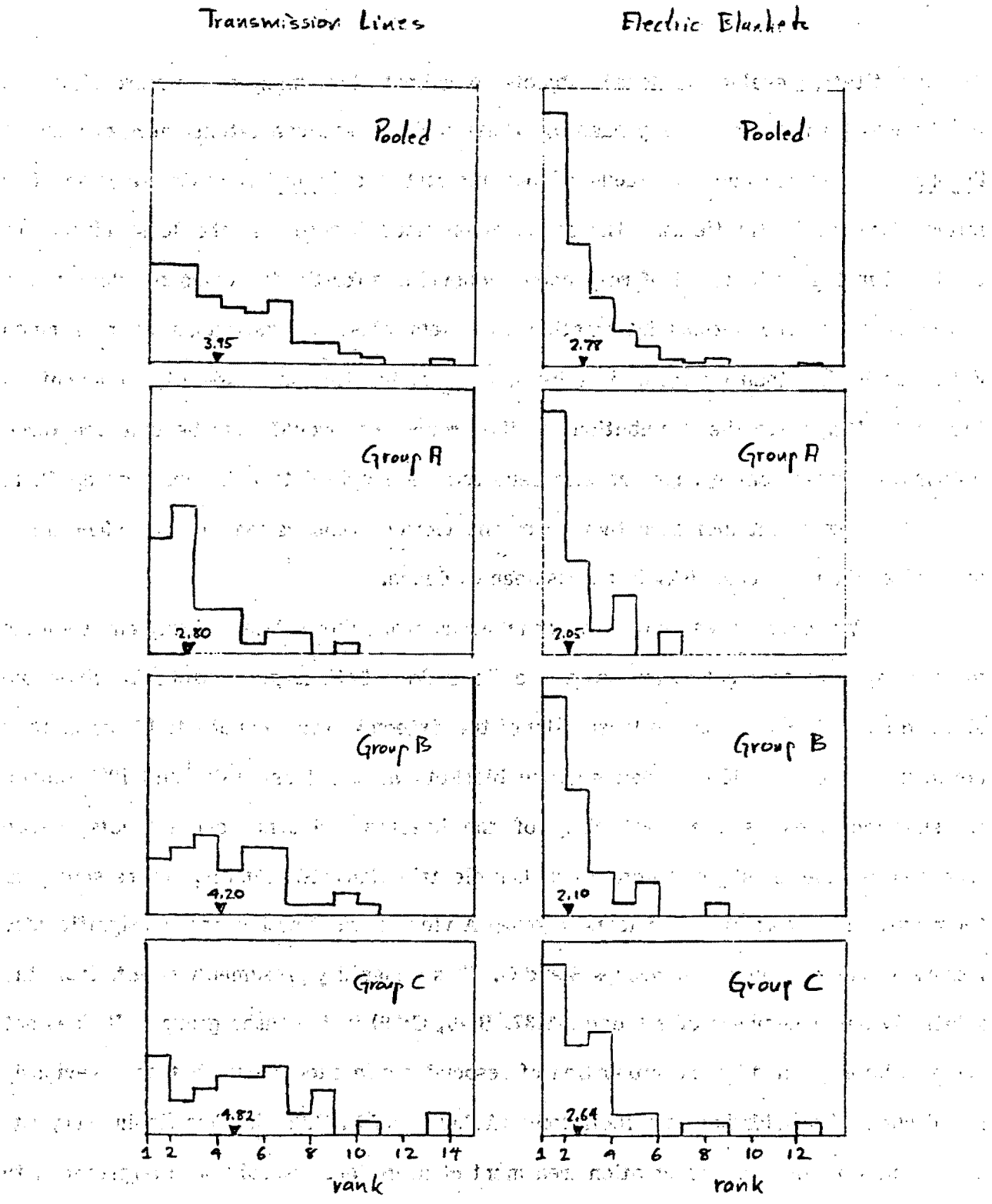


Figure 3: Rankings of the riskiness of field exposure from transmission lines (left) and electric blankets (right) in the set of other known or potential hazards. A rank of 1 means least risky of the sixteen. The top curve shows pooled results. The bottom curves show breakdowns for the three groups that subsequently became the three information treatment groups. Means are shown with solid triangles.

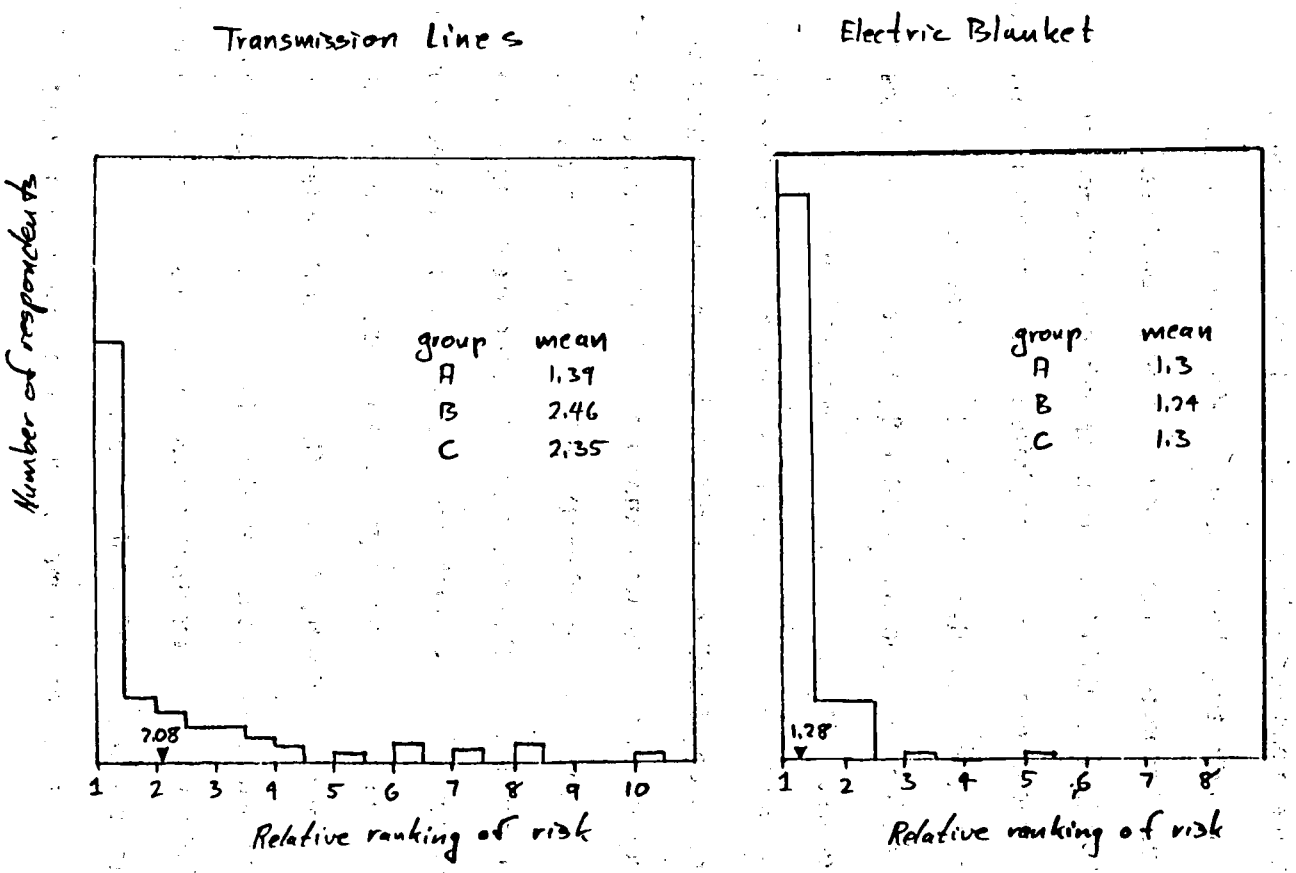


Figure 4: Judgments of relative riskiness of field exposure from transmission lines (left) and electric blankets (right). A judgment of 2.5 means the hazard is two and a half times as risky as the least risky hazard. Plots are for all respondents. Means are shown with solid triangles. Means of the three groups are also reported.

With this warning in mind, the left hand side of Figure 5 displays the mean scores for transmission lines for the nine risk attributes and two evaluative measures. The three vectors report results for the three information treatment groups, with the base of the vector indicating the mean score for the group before information was supplied and the point of the vector indicating the mean score after information was supplied. The right hand side of Figure 5 reports similar results for electric blankets.

In order to minimize the effects of prior opinions, and focus on relative shifts, we subtracted each respondent's score before information was supplied from the score obtained after information was supplied. Results obtained by pooling responses from all three information conditions are reported in Table 2. For transmission lines, those shifts in perception that occurred after information was received, and that show the greatest statistical significance, all tended to move the evaluation further out into the upper right quadrant of the factor space. Possible field effects from transmission lines were seen as more dread, less equitable and less well known to science for all three information treatment groups. Information also significantly reduced people's estimates of the number of people exposed to transmission line fields for all three treatment groups. A similar result obtained for electric blankets which were seen as significantly more dread and less well known to science. Information also significantly increased respondents estimates of the number of people exposed to electric blanket fields for all three treatment groups.

For both transmission lines and electric blankets, provision of information also increased people's concerns that existing control measures were not adequate and increased this tendency to "feel sure that this is a risk".

While the provision of information clearly produced significant shifts in the perceptions of our respondents, we found no persuasive evidence that changes in the details of the information we provided significantly affected the nature or magnitude of the shifts. Because of the demonstrated impact of our small group sizes, readers are

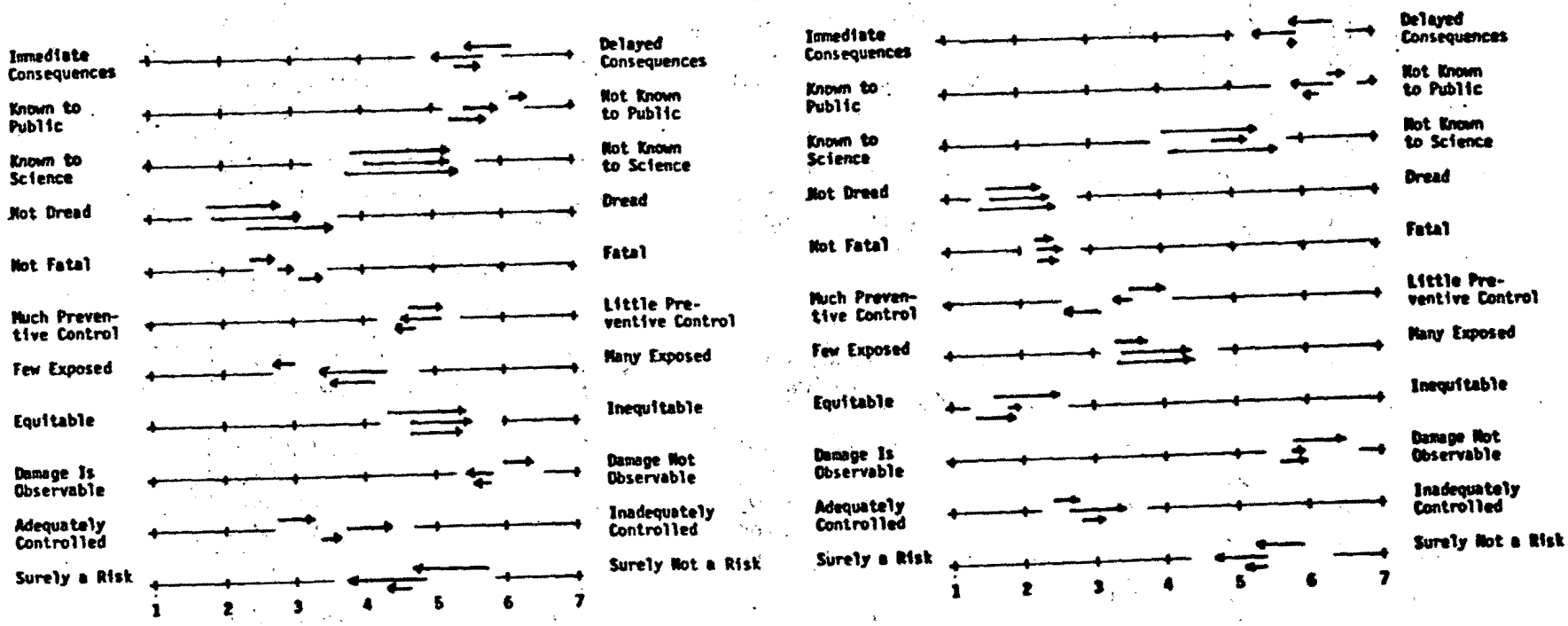


Figure 5: Comparison of the direction and magnitude of shifts in mean scores on the nine risk factors and two evaluative measures before (tail of vector) and after (point of vector) receiving specific information on possible field related health effects for transmission lines (left) and electric blankets (right). Information group A is the top vector, B is the middle, and C is the bottom.

TABLE 2: Pooled results for shift in responses on risk factors and evaluative measures after receiving specific information on possible field related health effects.

variable	mean shift	meaning	% of responses shifted negative	zero	positive
FOR TRANSMISSION LINES:					
Immediacy	- .41*	more immediate	46	23	39
Known to people	.15	less known	28	45	27
Known to science	1.36**	less known	17	17	66
Dread	1.20**	more dread	13	28	59
Severity	.21	more fatal	31	29	49
Controllable	- .12	more controllable	41	24	34
Number exposed	- .51*	fewer exposed	46	31	23
Equity	.89**	less equitable	19	32	49
Observability	- .03	more observable	35	38	27
Adequacy of control	.42*	inadequate control	28	28	45
Existence of risk	- .72**	more surely a risk	50	33	17
FOR ELECTRIC BLANKETS:					
Immediacy	- .34	less immediate	45	38	17
Known to people	- .16	less known	29	55	16
Known to science	1.16**	less known	21	25	54
Dread	.92**	more dread	9	43	47
Severity	.24	more fatal	22	39	40
Controllable	- .04	more controllable	40	28	33
Number exposed	.84**	more exposed	18	26	56
Equity	.22	less equitable	11	65	24
Observability	.30	less observable	27	39	34
Adequacy of control	.46	inadequate control	23	37	40
Existence of risk	- .58*	more surely a risk	48	34	17

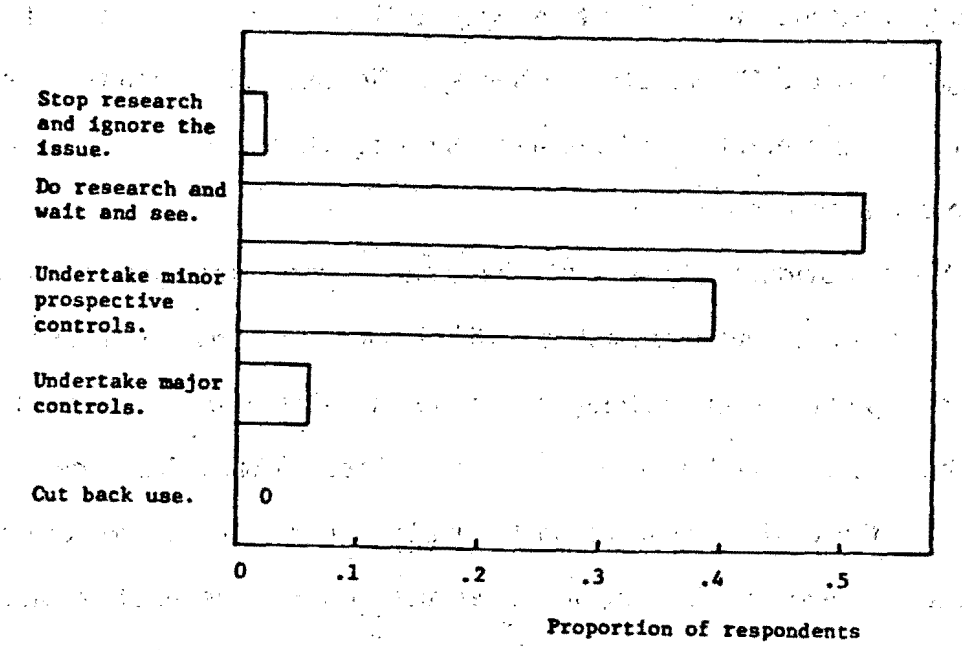
*p< .05; two tailed t test.
**p< .01; two tailed t test.

cautioned not to extend this finding to a positive finding that the details of information provided do not matter. The question of how specific kinds of information, and different styles and tone in presentation, effect short and long term shifts in perception, remains open, and deserves further study.

After providing subjects with information, we asked them to choose from a graduated set of risk management policies with respect to transmission line and electric blanket field exposure. The details of question wording are available elsewhere (6). Figure 6 shows the pooled results across the three information treatment classes. Consistent with the conjecture made on the basis of where these two potential hazards fall in the factor space, we find support for at most a modest level of regulatory control over transmission line field exposure. We find support for information dissemination on appliances but very little support for mandatory redesign or CPSC-like product bans. In analyzing these results by information treatment class, we found less stringent risk management responses from group A, the full information treatment group, than we found from the two partial information treatment groups. We believe that this result reflects the prior attitudes of the groups (Figures 2 and 3) and does not result from differences in the information provided.

Policy responses for transmission line exposure control were somewhat more stringent among those subjects who had previously heard about this topic and somewhat less stringent among subjects who live, or have lived, near a large powerline (6).

As a different measure of our subjects' views about regulatory policy, we asked how much more they would be willing to pay on a $100 per month electric bill in order to reduce the electric field exposures to people along and near high voltage transmission lines to half what they now are. The results are shown in Figure 7. Of course, there are potential problems with such "expressed preference" questions but the relatively low willingness to pay appears consistent with the other responses obtained in this study.



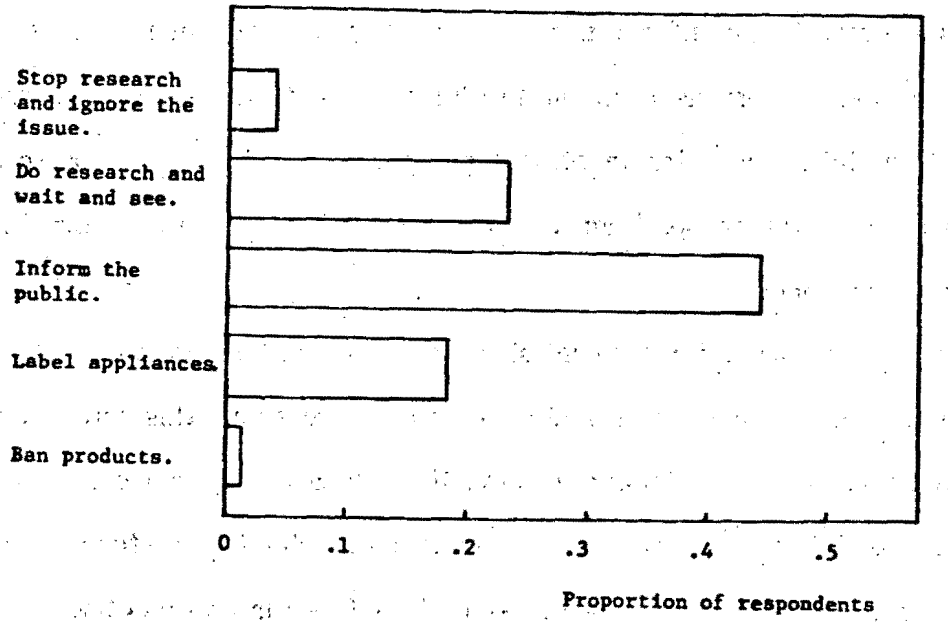


Figure 6: Distribution of policy choices with respect to transmission lines (above) and electric blankets (below). Pooled results across all three information treatment classes.

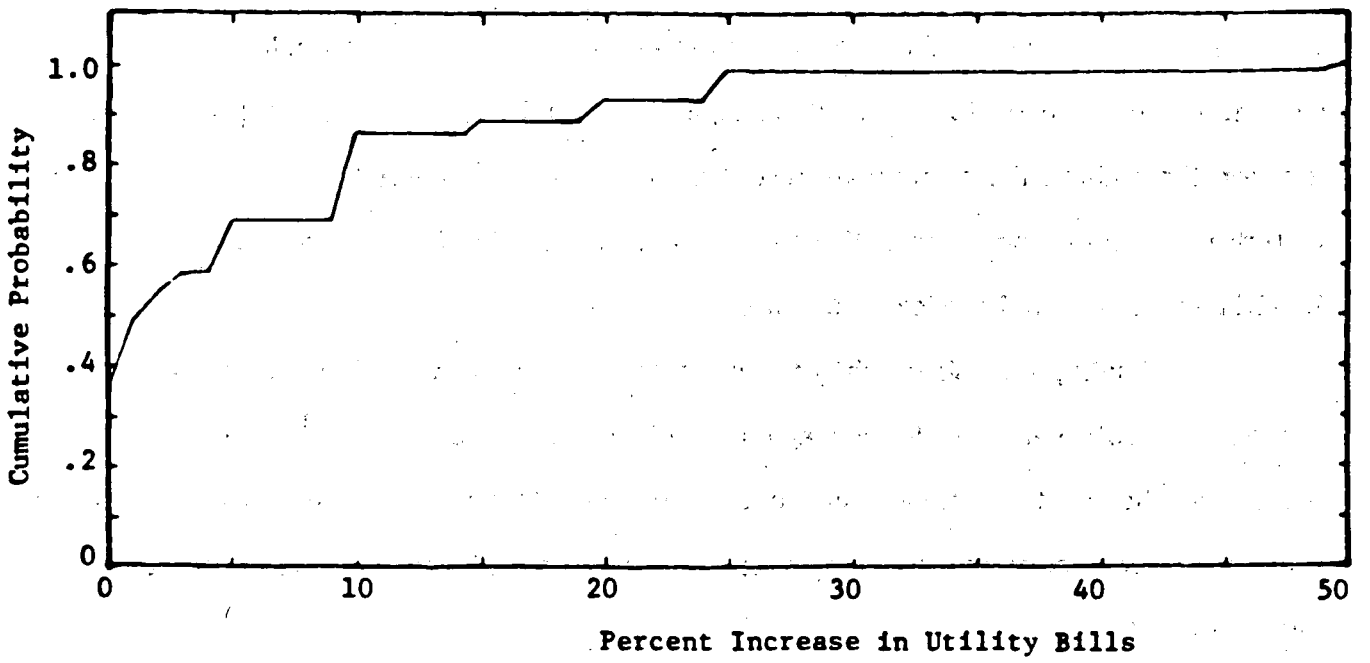


Figure 7: Cumulative distribution of willingness to pay to achieve a 50% reduction in transmission line field exposure (in terms of an increase in a 100 $/month utility bill). Pooled results across all three information treatment classes.

When these results were analyzed by information treatment class, the displayed variations in willingness to pay were consistent with the prior experiences and attitudes of the three groups. Respondents who now live or at some time have lived near lines displayed a slightly lower willingness to pay than those who had never lived near lines.

In the second part of the study, we described two possible mechanisms by which fields might give rise to effects, one involving stimulation of surface neural receptors such as those associated with hairs, the other involving interactions with complex organic molecules on the surface of cells. We pointed out that either could lead to the effects observed, and asked subjects whether one or the other would concern them more if it were proven to exist. Roughly 36% responded that either mechanism would concern them about the same, none responded that the hair stimulation mechanism would disturb them more, and roughly 62% responded that a mechanism involving direct cellular level interaction would concern them more.

Finally, we asked subjects questions about their views on the motivation of persons who intervene on electromagnetic field health issues in transmission line siting cases and the relative importance that should be attached to a number of factors in powerline siting decisions. Readers interested in these matters are referred to our DOE project report (6).

4. RESPONDENTS' "WORLD VIEWS"

Buss and Craik (15) have studied the possibility that peoples' perceptions of technologically induced risk are correlated with their broader "world view". They have identified two, and possibly three, distinct world views. They loosely identify "World View A" as being pro-technology, inclined toward rational decision processes, pro-growth, and so on, and "World View B" as being cool toward technology, inclined toward subjective and

participative decision process, cool on growth and so on.[7] While Buss and Craik found that world view was correlated with a subject's opinions about the appropriateness of alternative decision procedures (e.g., cost-benefit, political judgment, technical judgment, etc.), they found little or no correlation between world view and risk attributes for most hazards. However, several of the hazards that did show significant correlation fell in the upper right quadrant of the factor space of Figure 2.

At the end of Part 1 of our questionnaire, we asked our subjects to respond to three of the Buss and Craik world view questions. An analysis of the responses indicates that our subjects are very homogeneous in their views and fall strongly in World View A. This fact is unlikely to effect the generality of our findings for electric blankets because they fall in the upper left corner of the factor space of Figure 2 but may mean that our subjects responses for transmission lines are somewhat more positive toward technology (i.e., implying less risk, falling closer to the origin in the factor space of Figure 2, etc.) than the results one could expect from a broader sample of college educated opinion leaders.

5. CONCLUSIONS

This pilot risk perception study of human exposure to powerline frequency electromagnetic fields has illustrated how methods and results previously described in the risk perception literature can be used prospectively in analyzing perception of a potential, but as yet unsubstantiated, hazard. Our subjects did not view either transmission lines or electric blankets as particularly risky technologies. They appear to believe that only a modest regulatory involvement or control is required for fields from transmission lines and little or none for fields from electric blankets and other appliances.

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[7] The world views are actually defined in terms of correlation coefficients from a factor analysis. Data were obtained by presenting subjects with propositions such as "Decentralization of technology and of population are necessary if we are to have a humane, just and free society in the future" and asking them to respond on a multi-step scale that ranged from "strongly agree" to "strongly disagree". Thus, precise English characterizations of the make-up of the world views is not possible.

The provision of specific information about electric and magnetic fields and about possible health effects produced modest but statistically significant changes in the perceptions of our respondents, in the direction of making them more concerned about the risks. We observed no clear relation between the details of the information provided and the shifts that occurred. We do not have adequate evidence to draw conclusions about the existence of such an association.

Our subjects subscribe strongly to Buss and Craik's World View A (15). On the basis of Buss and Craik's work, we conclude that our findings for electric blankets can probably be generalized to the broader U.S. population of college educated opinion leaders. However, our findings for transmission lines may reflect a somewhat more favorable response response than could be expected from the broader U.S. population of college educated opinion leaders.

ACKNOWLEDGMENT

We acknowledge with pleasure the assistance of S. Lichtenstein, E. Morgan, R. Schmitt, P. Steranchak, C. Whipple, and an anonymous group of 116 alumni of Carnegie-Mellon University.

The experimental phase of the work was supported by the Carnegie-Mellon Center for Energy and Environmental Systems under a grant from the Benedum Foundation. The balance of the work was supported by Contract 19X-43342C from Oak Ridge National Laboratory in Cooperation with the Electric Energy Systems Division of the U.S. Department of Energy and by the National Science Foundation under Grant PRA-8116925 to Perceptronics, Inc. Carnegie-Mellon University also contributed discretionary institutional funds to this project.

Figure 1: Example page from part 1 of the questionnaire illustrating the form in which subjects were asked to evaluate the sixteen known or potential hazards.

Figure 2: Result of the factor solution for the sixteen known or potential hazards addressed in Part 1 of the study. A third factor, number of persons exposed, is not shown.

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Figure 7: Cumulative distribution of willingness to pay to achieve a 50% reduction in transmission line field exposure (in terms of an increase in a 100 $/month utility bill). Pooled results across all three information treatment classes.

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April 26, 1984

Dr. Paul Slovic
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Dear Paul:

Thanks for the edited manuscript. I have made most of the changes. A copy is enclosed. I would like to send it in to Risk Analysis as soon as I have had the figures re-drawn in ink. Let me know by telephone if you or Baruch or Don have any remaining concerns.

Three explanations. First, I changed the English a bit but did not move the section on the card sorting exercise. The reason is that the reader needs to have seen a description of the design of Part 2 before we can explain the results. Second, the reason you found the English on Figure 6 confusing is that I had glued up the wrong figure with the correct caption! That has been fixed. Third, I clarified the argument about lines and blankets in the world view discussion at the end. It has to do with their location in the factor space and Buss and Craik's correlation.

Yours,

Granger

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Enclosure

Check acknowledgment

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April 2[illegible], 19[illegible]

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Yours,

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Enclosure

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