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Perception of Risks From Electromagnetic Fields: A Psychometric Evaluation of a Risk-Communication Approach

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Potential health risks from exposure to power-frequency electromagnetic fields (EMF) have become an issue of significant public concern. This study evaluates a brochure designed to communicate EMF health risks from a scientific perspective. The study utilized a pretest–posttest design in which respondents judged various sources of EMF (and other) health and safety risks, both before reading the brochure and after. Respondents assessed risks on dimensions similar to those utilized in previous studies of risk perception. In addition, detailed ratings were made that probed respondents' beliefs about the possible causal effects of EMF exposure. The findings suggest that naive beliefs about the potential of EMF exposure to cause harm were highly influenced by specific content elements of the brochure. The implications for using risk-communication approaches based on communicating scientific uncertainty are discussed.

KEY WORDS: Risk communication; risk perception; electromagnetic fields.

1. INTRODUCTION

The large-scale generation, distribution, and use of electric power are one of industrialized society's more significant technological accomplishments of this century. Many of the commonplace amenities of everyday life at home and in industry are dependent upon a readily available and relatively inexpensive supply of electrical energy.

Though the widespread distribution and use of electrical power encountered both technological and regulatory barriers during the early stages of its development, the past several decades have seen a continued expansion of power distribution systems, as well as increased power consumption, in virtually all industrialized countries. Aside from electrical shock, which has always been a hazard, relatively few problems have surfaced to cast a specter of risk on an otherwise well-received, and now familiar, technology.

Recent research on the potential health effects of exposure to electromagnetic fields has brought the distribution and use of electrical power into the limelight of public concern.[1] However, while some epidemiological studies have identified potential cancer risks to human populations,[2–4] other studies are unable to establish a firm causal link between EMF exposure and cancer.[5] Nonetheless, public reaction to possible EMF health effects has had important impacts on the power industry, particularly the siting of new high-voltage transmission lines, and poses challenging problems for risk management.[6,7]

A critical issue for industry and government is how to communicate with the public about EMF and its potential health risks. What models of risk can be used as a basis for risk communication, and how will the public likely react to new information about EMF? This paper presents a psychometric evaluation of one approach to

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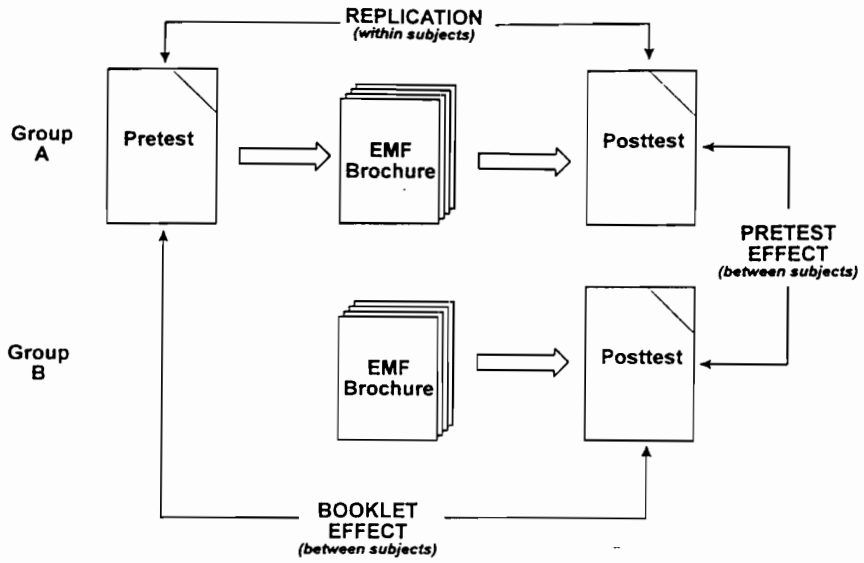

Fig. 1. Design of EMF replication study.

EMF health risk communication based on a booklet about EMF and related health effect research, of the type that public and private utilities might provide to community members or the media. The evaluation approach is designed around a psychometric model of risk that has been used to assess risk perceptions in other technological contexts.[8,9]

2. METHOD

2.1. Overview of Research Design

The study involved presenting a group of individuals with a questionnaire designed to elicit perceptions and beliefs about EMF health risks, as well as attitudes toward EMF health risk regulation. An initial study was done in July of 1990, in which a questionnaire was administered twice to each participant in a pretest–posttest design. Between the two administrations, participants read a 16-page brochure[10] that gave a description of EMF, the kinds of studies that have been done on EMF health effects, and possible options for mitigation and regulation. The brochure was given to participants to read immediately after they completed the pretest, and the posttest was administered immediately after they completed reading the brochure. The entire package was self-administered.

A second study was done in April 1993 to replicate the 1990 study and to provide an additional control group to permit examination of possible pretest sensitization effects. Figure 1 shows a schematic of the design of the replication study.

Two groups were given the booklet and administered the questionnaire. Group A received a pretest survey followed by the brochure and the posttest survey administered identically to respondents in the 1990 study. Group B received only the EMF brochure, followed by the same posttest questionnaire received by respondents in Group A.

This design permits three comparisons. First, replication of the 1990 results can be tested by a within-subjects comparison of the Group A pretest and posttest. Second, a between-subjects comparison of the Group A and Group B posttests would reveal a sensitization effect of the pretest for material in the brochure. Finally, a between-subjects comparison of the Group A pretest with the Group B posttest provides a booklet effect test uncontaminated by possible sensitizing effects of the pretest. Though the between-subjects comparisons have a lower statistical power than the within-subjects comparisons, the effects that emerge are stronger and have potentially greater policy relevance.

2.2. The Brochure

The brochure respondents were given was entitled "Electric and Magnetic Fields from 60 Hz Electric Power: Briefly, What Do We Know About Possible Health Risks?"[4] The content of the brochure was pro-

[4] A copy of the brochure is available from the first author.

Table I. Major Headings of the EMF Risk-Communication Brochure "Electric and Magnetic Fields from 60 Hertz Electric Power: Briefly, What Do We Know About Possible Health Risks?"

- What Is the Point of This Brochure?
- What Are 60 Hertz (Hz) Electric and Magnetic Fields?
- Are 60 Hz Fields Like X-Rays or Microwaves?
- What Kinds of Studies Have Been Done to Look for Possible Health Effects from 60 Hz Fields? What Has Been Learned?
- If There Is a Risk, Are Weaker Fields Safer than Stronger Fields?
- What Can Be Done? What Should Be Done?
- Haven't Some States Passed Standards for Fields from Transmission Lines?
- Do 60 Hz Fields from Power Lines Pose Significant Risks to Farm Crops, Farm Animals, or the Environment?
- Summary

duced by Professor Granger Morgan and his colleagues at the Department of Engineering and Public Policy at Carnegie Mellon University (CMU), as well as other outside technical experts and reviewers. The brochure was adapted by CMU from a larger booklet with a similar title that was developed as part of a major research effort sponsored by the Electric Power Research Institute (EPRI) to understand how to communicate the potential health risks of EMF exposure. Over 100,000 copies of the booklet were distributed to interested individuals, other researchers, and various organizations in the electric power industry including utilities. The content of the booklet has come to form the information kernel of the public information programs on EMF health risks of many local utilities. Arguably, the content of the booklet represents one of the largest national-level risk communication programs, comparable to that for the health risks of radon exposure.

Like the booklet from which it was adapted, the brochure was developed as a general introduction to EMF and its potential health risks, with an orientation toward the science of EMF health risk research. Table I shows a general outline of the brochure and presents its main headings. Its succinct, 16-page presentation made the brochure similar to the kinds of information presentations produced for the public by utilities and industry groups.[11]

The content attempts to provide a definitional overview of EMF and a presentation of the science concerning health effects. As such, it is an "over-the-shoulder" look at the scientific evidence on EMF health effects, including considerable discussion of the scientific uncertainty surrounding existing research. As part of this discussion, the text mentions appliances and electrical devices found in the home or office, particularly toasters, electric blankets, hair dryers, video displays, televisions, speed controllers, dimmer switches, electrically heated water beds, and small electric motors. X-rays and microwaves are compared and contrasted with EMF as sources of radiation. In its review of research on health effects, various biological mechanisms and health disorders are mentioned, including heart rate, reaction time, brain cancer, birth defects, chronic depression, and neurological disorders.

2.3. The Survey Instrument

The survey instrument for the within-subjects condition was divided into three parts as follows: *Part One* was a questionnaire asking for attitudes and opinions about various kinds of risks, some involving electromagnetic fields and some not. *Part Two* presented the brochure produced at CMU. Participants were asked to read this brochure carefully before going on to Part Three of the questionnaire. *Part Three* repeated many of the questions in Part One, to assess the effect of the brochure (Part Two) upon attitudes and perceptions. Specifically, the components of Parts one and three that were repeated were the following.

2.3.1. Psychometric Scales

Twenty-two activities, substances, or technologies were rated on each of eight scales relevant to perceived risks and benefits. The 22 items included four that exposed people to electromagnetic fields: electric blankets, hair dryers, large power lines, and electric can openers. In addition, there was an item pertaining to another form of nonionizing radiation (microwave ovens) and 17 items covering a diverse array of hazards (e.g., automobiles, pesticides, handguns, dams, prescription drugs, etc.). The items pertaining to EMF specified that the risks to be rated were those from electric and magnetic fields and not risks from shock or fire.

The eight scales were chosen to represent scales that have been found to be important in prior risk-perception research. They were risk to those exposed, benefit to society, knowledge about the risk held by people who are exposed, knowledge about the risk held by scientists, dread, severity of consequences (if a mishap occurs), control over the risk, and equity in the distribution of benefits and risks.

Table II presents the wording and labels for all eight scales. Each respondent rated all 22 items on all eight scales in Part One. However, in Part Three, after the brochure had been read, ratings were made on the

Table II. Scales on Which 22 Hazard Items Were Rated

Risk			
To what degree does this activity, substance, or technology present a risk to those who are exposed?			
	not risky	1 2 3 4 5 6 7	extremely risky
Benefit to Society			
To what degree does this activity, substance, or technology provide important benefits to society?			
	little or no benefit	1 2 3 4 5 6 7	very important benefits
Knowledge About Risk			
To what extent are the risks well understood by people who are exposed?			
	risk level not well-known	1 2 3 4 5 6 7	risk level very well-known
Known to Science			
To what extent are the risks well-known and understood by scientists?			
	risks not well-known	1 2 3 4 5 6 7	risks well-known
Dread			
Is this a risk that people dread—on the level of a gut reaction?			
	no dread	1 2 3 4 5 6 7	dread
Severity of Consequences			
When the risk from this activity, substance, or technology is realized in the form of a mishap or illness, how likely it is that the consequences will be fatal?			
	certain not to be fatal	1 2 3 4 5 6 7	certain to be fatal
Control Over Risk			
Risks can be controlled either by preventing mishaps and illnesses or by reducing the severity of mishaps and illnesses after they occur. To what extent can people, by personal skill or diligence, avoid injury, illness, or fatality?			
	personal risk can't be controlled	1 2 3 4 5 6 7	personal risk can be controlled
Equity			
To what extent do those who are exposed to the risks fairly share in the benefits?			
	risks and benefits fairly distributed	1 2 3 4 5 6 7	risks and benefits unfairly distributed

eight scales only for the 4 items involving electric and magnetic fields.

2.3.2. Other Scales in Parts One and Three

The psychometric scales were followed by a variety of attitudinal, opinion, and perception questions. These items included questions about

- health effects of various substances, activities, and technologies (including electromagnetic fields) on the human nervous system;
- the degree to which electromagnetic fields might interfere with normal operation of various human and nonhuman systems (e.g., television signals, animal migrating patterns, human immune system);
- the degree to which electromagnetic fields may be an important cause of human social and health disorders (e.g., ulcers, mental illness, gang violence, cancer); and
- assessed attitudes toward various risk-management options pertaining to fields (e.g., do nothing, put all high-voltage transmission lines underground, require various types of warning signs, etc.).[5]

2.4. Respondents

Respondents for the study were obtained through an ad placed in the University of Oregon community newspaper in July 1990. A total of 60 individuals participated in the 1990 study, of which 34 were men and 26 were women. A total of 139 individuals participated in the 1993 replication study, 70 in Group A and 69 in

[5] A complete version of the survey instrument is available from the first author.

Group B. Their mean age was 26 years (range, 17 to 46 years). Each respondent was paid $10 for participating in the study, which took approximately 1 to 1.5 hr to complete.

About 59% of the respondents claimed to have heard about the possible health risks of exposure to electromagnetic fields. Of these, most (80%) claimed they were informed by newspapers or magazines, or by discussions with friends or relatives (62.9%). About 30% claimed to have lived near a high-voltage transmission line and 42% said they have lived in a residence with ceiling heat.

3. RESULTS

3.1. Psychometric Scales—1990 Study

Table III presents the ordered mean ratings for all 22 items on each of the eight scales for the July 1990 administration. These ratings were made in Part One of the survey, before the respondents read the brochure. The four EMF items are marked with asterisks. In general, electric can openers, hair dryers, and electric blankets were perceived similarly toward the extreme low end of the distribution with regard to risk, severity of consequences, dread, and knowledge. They were seen as extremely equitable in their risk/benefit distributions, low on benefits, and high on controllability of risk. The largest difference among the three was in perceived risk, with electric blankets being perceived as substantially higher in risk than can openers. Large power lines stood out among the four EMF items as being perceived higher in risk, severity of consequences, dread, and benefit; lower on control and less equitable. Power-line risks were perceived as better known to both science and to those exposed, relative to the other EMF items. Microwave ovens were consistently rated as somewhat less risky and less beneficial than power lines but more risky and beneficial than the other EMF items. One additional finding of interest in Table III is that each of the four EMF risks was judged better known to science than to those persons exposed to such risks.

Table IV presents, for the four EMF items, the mean ratings on each scale before and after reading the brochure. Also presented is a summary of the number of persons whose ratings decreased, stayed the same, and increased after reading the brochure, along with an indication of whether the mean change in the two ratings was statistically significant.

Table IV shows that the mean ratings of risk increased substantially after exposure to the brochure. The percentage of persons whose risk ratings increased ranged from 56% (power lines) to 76% (electric can openers). Decreased ratings of risk ranged from 28% (power lines) to 8% (electric blankets). The increases in mean perceived risk were substantial enough to move each item considerably higher in the ranking across the 22 items. Specifically, electric blankets moved from 8th to 17th (where 1 = lowest risk); hair dryers, from 2nd to 14th; large power lines, from 16th to 18th; and electric can openers, from lowest in the list to 11th (these rank changes assume that the means for other items would not have changed).

Other statistically significant changes occurred with benefit (higher for power lines), known to science (lower for power lines), dread (higher for power lines), control (higher for all four items), and equity (risks from electric blankets and hair dryers were presumed as less fairly distributed).

The meaning of the increase in perceived control is not clear. We speculate that the brochure led people to see the risks as more controllable through avoidance of exposure to fields produced by the item.

Finally, although dread increased substantially for power lines, there was rather little change in dread for the other three items.

The increased perceptions of risk from electric blankets and power lines after receipt of information is consistent with the results obtained by Morgan et al. in their survey of Carnegie Mellon alumni.[12] Morgan *et al.* also found that information led their respondents to see risks from these two EMF items as more dreaded, less equitable, and better known to science. The first two of these results are similar to results from the present study; the third differs.

3.2. Psychometric Scales—1993 Replication

Table V shows the mean risk ratings for the four EMF items for the April 1993 replication group. As before, perceived risk for all four EMF items was significantly elevated after reading the brochure. Significant differences in risk ratings were also observed for electric can openers on the scales benefits, severity of consequences, and equity; large power lines on dread; and hair dryers on equity. The principal difference between the 1990 administration and the 1993 replication was for the control scale, where the brochure resulted in significantly increased perceptions of control in 1990 but not in the 1993 replication group. Overall, however, the pat-

Table III. Ordered Means for 22 Items on Eight Scales

Perceived Risk		Benefit		Known to Exposed		Known to Science	
* Electric can openers	1.94	Cigarette smoking	1.11	* Electric can openers	1.95	* Electric can openers	3.85
* Hair dryers	2.59	Handguns	1.68	* Electric blankets	2.00	* Hair dryers	4.04
Large dams	2.81	Multiple homosexual partners	1.70	Plastic food containers	2.09	Plastic food containers	4.45
Bicycles	2.97	* Electric can openers	1.97	* Hair dryers	2.22	Computer display screens	4.49
Power lawn mowers	3.09	* Electric blankets	2.09	Home weatherization	2.48	Genetic engineering research	4.58
Plastic food containers	3.17	* Hair dryers	2.22	Genetic engineering research	2.50	* Electric blankets	4.64
Computer display screens	3.22	Caffeine	2.29	Microwave ovens	2.68	Home weatherization	4.71
* Electric blankets	3.22	Plastic food containers	2.75	Computer display screens	2.75	Power lawn mowers	4.85
Commercial aviation	3.24	Pesticides	2.91	* Large power lines	3.07	Bicycles	4.86
Microwave ovens	3.30	Nuclear reactors	3.23	Pesticides	3.16	Microwave ovens	4.96
Home weatherization	3.48	Microwave ovens	3.31	Power lawn mowers	3.54	* Large power lines	5.05
Genetic engineering research	3.60	Power lawn mowers	3.34	Large dams	3.55	Large dams	5.30
Caffeine	3.76	Home weatherization	4.04	Prescription drugs	3.85	Prescription drugs	5.47
Prescription drugs	3.95	Genetic engineering research	4.50	Caffeine	4.22	Commercial aviation	5.53
Diagnostic X-rays	4.19	Computer display screens	4.69	Bicycles	4.24	Caffeine	5.65
* Large power lines	4.33	* Large power lines	4.72	Diagnostic X-rays	4.25	Pesticides	5.70
Automobiles	4.92	Commercial aviation	4.93	Commercial aviation	4.63	Diagnostic X-rays	6.02
Pesticides	5.23	Automobiles	4.98	Nuclear reactors	5.12	Nuclear reactors	6.11
Nuclear reactors	5.88	Prescription drugs	5.05	Automobiles	5.24	Handguns	6.21
Cigarette smoking	6.10	Large dams	5.06	Handguns	5.78	Automobiles	6.32
Handguns	6.10	Bicycles	5.55	Multiple homosexual partners	6.00	Multiple homosexual partners	6.44
Multiple homosexual partners	6.31	Diagnostic X-rays	5.57	Cigarette smoking	6.25	Cigarette smoking	6.73
Dread		**Severity of Consequences**		**Control**		**Equity**	
* Electric can openers	1.49	* Electric can openers	1.90	Nuclear reactors	2.38	* Hair dryers	1.92
* Hair dryers	1.67	Computer display screens	2.55	Genetic engineering research	2.98	* Electric blankets	2.11
* Electric blankets	1.79	* Hair dryers	2.69	Large dams	3.07	* Electric can openers	2.13
Plastic food containers	2.09	* Electric blankets	2.90	* Large power lines	3.33	Bicycles	2.20
Bicycles	2.14	Plastic food containers	2.93	Commercial aviation	3.67	Caffeine	2.30
Microwave ovens	2.33	Caffeine	2.97	Diagnostic X-rays	4.21	Microwave ovens	2.38
Home weatherization	2.35	Home weatherization	3.04	Pesticides	4.42	Power lawn mowers	2.50
Computer display screens	2.40	Microwave ovens	3.16	Home weatherization	4.50	Diagnostic X-rays	2.66
Power lawn mowers	2.54	Power lawn mowers	3.21	Plastic food containers	4.69	Plastic food containers	3.02
Large dams	2.74	Genetic engineering research	3.50	Computer display screens	4.75	Home weatherization	3.12
Caffeine	2.76	Bicycles	3.51	Prescription drugs	4.80	Computer display screens	3.21
* Large power lines	2.96	Diagnostic X-rays	4.11	Handguns	4.85	Commercial aviation	3.25
Prescription drugs	3.26	* Large power lines	4.16	Automobiles	5.05	Automobiles	3.33
Genetic engineering research	3.64	Prescription drugs	4.45	Microwave ovens	5.21	Prescription drugs	3.34
Automobiles	3.69	Pesticides	5.00	Bicycles	5.30	Multiple homosexual partners	3.59
Diagnostic X-rays	3.75	Large dams	5.12	* Hair dryers	5.59	Large dams	4.00
Pesticides	4.41	Automobiles	5.12	Power lawn mowers	5.63	Genetic engineering research	4.35
Commercial aviation	4.47	Commercial aviation	5.72	Cigarette smoking	5.66	* Large power lines	4.44
Cigarette smoking	5.37	Cigarette smoking	5.80	* Electric can openers	5.67	Pesticides	5.08
Handguns	5.67	Nuclear reactors	6.07	* Electric blankets	5.74	Cigarette smoking	5.36
Nuclear reactors	6.00	Multiple homosexual partners	6.21	Multiple homosexual partners	6.10	Nuclear reactors	5.49
Multiple homosexual partners	6.09	Handguns	6.27	Caffeine	6.12	Handguns	5.71

* EMF items.

tern of risk perceptions was quite stable over the time interval between administrations.

Tables VI and VII present between-subjects analyses of the effect of the booklet and the pretest on risk ratings for the four EMF items. As with both the original and the replication studies, the booklet had significant effect on perceived risk for all four EMF items (see Table VI). Though there was some sensitization to material in the brochure by the pretest, particularly for the items hair dryers and electric can openers (see Table VII), the effect of the pretest on posttest ratings was not as great as the effect of the brochure.

Table IV. Mean Ratings Before and After Reading the Brochure, July 1990

	Electric blankets			Hair dryers			Large power lines			Electric can openers		
	Pretest		Post test	Pretest		Post test	Pretest		Post test	Pretest		Post test
Perceived Risk (1 = low risk)	3.22	*** 4-9-37[a]	4.46	2.60	*** 8-6-36	3.84	4.30	** 15-9-30	5.04	1.94	*** 9-6-38	3.30
Benefit (1 = low benefit)	2.09	19-30-9	2.00	2.22	17-27-15	2.20	4.72	* 10-23-25	5.22	1.97	17-33-9	1.76
Known to Exposed (1 = not known)	1.98	15-25-15	2.15	2.19	20-23-14	2.07	3.07	20-13-24	3.49	1.94	15-26-14	1.94
Known to Science (1 = not known)	4.64	20-15-12	4.27	4.04	22-11-16	3.94	5.05	* 20-18-17	4.58	3.85	22-13-13	3.67
Dread (1 = no dread)	1.75	7-30-19	2.00	1.62	8-35-13	1.71	2.94	*** 8-12-36	4.07	1.46	5-39-12	1.62
Severity of Consequences (1 = not fatal)	2.90	15-13-20	3.10	2.71	16-18-15	2.71	4.22	19-12-20	4.18	1.96	8-19-18	2.31
Control (1 = no control)	5.73	** 4-27-25	6.45	5.57	* 7-26-24	6.19	3.31	** 14-12-31	4.04	5.66	** 6-23-27	6.34
Equity (1 = very fair)	2.09	** 8-24-21	3.09	1.92	* 6-29-17	2.69	4.45	20-17-19	4.29	1.54	10-25-16	1.78

[a] The three values in each cell represent the number of respondents whose ratings decreased, stayed the same, and increased after reading the brochure. Persons who gave "don't know" responses on one or both occasions are excluded from this analysis.

* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.

Table V. Mean Ratings Before and After Reading the Brochure, April 1993: Replication Group

	Electric blankets			Hair dryers			Large power lines			Electric can openers		
	Pretest		Posttest	Pretest		Posttest	Pretest		Posttest	Pretest		Posttest
Perceived Risk (1=low risk)	2.76	*** 6-12-48[a]	4.25	2.14	*** 5-8-56	3.87	3.57	*** 9-14-46	4.83	1.70	*** 4-13-49	3.17
Benefit (1=low benefit)	2.19	24-31-14	1.91	2.50	21-31-18	2.41	4.94	23-26-21	4.96	2.24	* 21-42-7	1.91
Known to Exposed (1=not known)	2.09	18-32-16	1.96	1.98	16-28-22	2.07	3.15	21-20-26	3.13	2.11	16-36-14	1.84
Known to Science (1=not known)	4.54	18-32-16	4.16	4.06	16-28-22	4.11	4.82	21-20-26	4.81	4.00	16-36-14	4.00
Dread (1=no dread)	1.67	15-37-15	1.83	1.57	8-45-17	1.71	3.01	* 14-23-31	3.57	1.51	9-46-13	1.58
Severity of Consequences (1=not fatal)	2.58	16-14-29	3.05	2.81	18-19-25	2.92	4.20	22-11-29	4.33	1.98	** 6-23-31	2.66
Control (1=no control)	5.82	16-32-20	5.93	5.32	19-25-25	5.76	3.36	18-18-33	3.83	5.68	16-36-16	5.71
Equity (1=very fair)	2.93	16-21-20	3.43	2.74	* 10-33-20	3.24	3.80	23-16-21	3.86	2.57	* 11-27-24	3.18

[a] The three values in each cell represent the number of respondents whose ratings decreased, stayed the same, and increased after reading the brochure. Persons who gave "don't know" responses on one or both occasions are excluded from this analysis.

* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.

Table VI. Mean Ratings: Pretest vs. Control Group (Brochure Effect)[a]

	Electric blankets			Hair dryers			Large power lines			Electric can openers		
	Pretest		Control	Pretest		Control	Pretest		Control	Pretest		Control
Perceived Risk (1=low risk)	2.76	***	3.85	2.14	***	3.18	3.57	***	4.49	1.70	***	2.53
Benefit (1=low benefit)	2.19	N.S.	2.41	2.50	N.S.	2.70	4.94	**	5.70	2.24	N.S.	2.09
Known to Exposed (1=not known)	2.09	N.S.	2.10	1.98	N.S.	1.84	3.15	N.S.	3.28	2.11	*	1.57
Known to Science (1=not known)	4.54	**	3.61	4.06	**	3.30	4.82	N.S.	4.38	4.00	*	3.23
Dread (1=no dread)	1.68	**	2.20	1.57	N.S.	1.94	3.01	***	4.10	1.51	N.S.	1.67
Severity of Consequences (1=not fatal)	2.58	N.S.	2.92	2.81	N.S.	2.79	4.20	N.S.	4.65	1.98	N.S.	2.38
Control (1=no control)	5.82	N.S.	5.93	5.32	*	5.94	3.36	N.S.	3.49	5.68	N.S.	5.80
Equity (1=very fair)	2.93	N.S.	3.13	2.74	N.S.	2.89	3.80	N.S.	4.36	2.57	N.S.	3.18

[a] Only significant values are noted.
* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.

Table VII. Mean Ratings: Control vs. Posttest Group (Pretest Effect)[a]

	Electric blankets			Hair dryers			Large power lines			Electric can openers		
	Control		Posttest	Control		Posttest	Control		Posttest	Control		Posttest
Perceived Risk (1=low risk)	3.85	N.S.	4.25	3.18	**	3.87	4.49	N.S.	4.83	2.53	**	3.17
Benefit (1=low benefit)	2.41	*	1.91	2.70	N.S.	2.41	5.70	**	4.96	2.09	N.S.	1.91
Known to Exposed (1=not known)	2.10	N.S.	1.95	1.84	N.S.	2.07	3.27	N.S.	3.13	1.56	N.S.	1.84
Known to Science (1=not known)	3.61	*	4.16	3.30	**	4.11	4.38	N.S.	4.81	3.23	*	4.00
Dread (1=no dread)	2.20	N.S.	1.83	1.94	N.S.	1.71	4.10	N.S.	3.57	1.67	N.S.	1.58
Severity of Consequences (1=not fatal)	2.92	N.S.	3.05	2.79	N.S.	2.92	4.65	N.S.	4.33	2.38	N.S.	2.66
Control (1=no control)	5.93	N.S.	5.93	5.94	N.S.	5.76	3.49	N.S.	3.83	5.80	N.S.	5.71
Equity (1=very fair)	3.13	N.S.	3.43	2.89	N.S.	3.24	4.36	N.S.	3.86	3.18	N.S.	3.18

[a] Only significant values are noted.
* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.

3.3. Health Effects on the Nervous System

Subjects were asked to indicate the degree to which a number of technologies, substances, and activities "interferes with the normal operation of the nervous system." Table VIII presents basic data from the questions about the effects of various factors (including EMF) upon the human nervous system. The percentages of respondents indicating "moderate" or "strong interference" for each item before and after reading the brochure (excluding "don't know" responses) are presented for the 1990 group, the 1993 replication group, and the 1993 control group. Significance tests indicated in Table VI were performed on the means of subjects ratings, where a value of 1 was assigned to "no interference" and a value of 4 was assigned to "strong interference." The column labeled "pretest effect" indicates the significance level of a comparison of the posttest for the 1993 replication group (column 4) vs. the control group (column 5). Significance tests indicated in the column labeled "control group" are between control group means and pretest means for the 1993 replication group (column 3). Thus, the contents of Table VIII (and subsequent tables similarly organized) allow the complete set of comparisons identified in Fig. 1.

The data in Table VIII show that interference with the nervous system was judged higher in the 1990 study for street drugs, EMF, and X rays. In the 1993 replication group, significantly higher interference ratings were also found for EMF and X-ray as well as the electromagnetic radiation sources microwave ovens and television signals. The significant effect for street drugs in the 1990 study failed to reappear in the replication.

The same pattern of significance for EMF-related items was also present in the between-subjects control group (booklet effect) test. Here, interference ratings for microwave ovens, television signals, and X rays were elevated as a result of reading the brochure. Ratings for EMF were in the direction of higher interference, but not significantly so. The between-subjects tests, however, have less statistical power than the within-subjects tests, making the effects observed in these tests of potentially greater practical importance. The only item showing a significant pretest sensitization effect was pesticides, an effect also shown in the 1993 replication group results. Since the brochure did not discuss pesticides in the context of EMF, we have no explanation for this result.

The bottom of Table VIII shows the results for four specific EMF items. Three of the four items had significantly higher interference ratings in the 1990 study after reading the brochure (high-voltage transmission lines excepted). For the 1993 replication group, all four items exhibited significantly elevated interference ratings from pretest to posttest. The between-subjects control group tests were also significant for all four EMF items. However, some pretest sensitization occurred, particularly for electric blankets and hair dryers, though the degree of that sensitization was less than the effect of the booklet alone on posttest ratings.

Despite the sharp increases in perceived interference of EMF items after reading the brochure, these items were still judged to interfere less with the nervous system than most of the other items, such as alcohol, smoking, pesticides, street drugs, and stress.

3.4. Effects of Electromagnetic Fields on Mechanical and Biological Systems

Subjects were given a number of items relating to mechanical and biological systems. For each item they were asked to indicate "the degree to which you think that exposure to electromagnetic fields might interfere with normal operation." Ratings ranged from 1 = "no interference" to 4 = "strong interference." Intermediated values were 2 = "slight interference" and 3 = "moderate interference." Table IX summarizes these judgments and is organized in a similar fashion to the previous table.

Looking at the percentages of 1990 study respondents giving ratings of "moderate" or "strong interference," we see that, prior to the brochure, EMF was perceived to have the strongest impact on radio and TV signals, followed by slight to moderate impacts on the human nervous system, mental health, weather satellites, and cell growth and reproduction. After the brochure had been read, interference ratings were about as high for the human nervous system and cell growth as for radio and TV, though only radio and TV exhibited significantly different mean ratings from pretest and posttest.

The same general results were obtained in the 1993 replication group, though the pattern of statistical significance was much stronger. Highly significant effects on interference ratings were obtained for biological systems including: human nervous and digestive systems, thinking and problem solving, human immune system, spread of diseases, cell growth and reproduction, and animal migratory patterns. Significant interference effects were also found for household smoke detectors and microwave ovens.

Control group comparisons, while generally in the direction of higher interference ratings after reading the

Table VIII. Beliefs About Potential Sources of Interference with Normal Operation of Nervous System

	Moderate or strong interference (%)					
	1990 study		1993 replication		Control group	Pretest effect[a]
	Pretest	Posttest	Pretest	Posttest		
Microwave oven	10.2	20.3	14.3	32.9*	31.4**	n.s.
Marijuana	71.2	71.2	88.6	82.9	90.0	n.s.
Street drugs	96.6	94.9*	98.6	98.6	98.6	n.s.
Television signals	32.2	28.8	10.0	27.1***	28.6*	n.s.
Diet	78.0	72.9	64.3	64.3	80.0	n.s.
Noise	76.3	67.8	41.4	44.3	45.7	n.s.
Stress	93.2	93.2	84.3	81.4	90.0	n.s.
Smoking	84.8	91.5	91.4	90.0	95.7	n.s.
Electromagnetic fields	44.1	62.7*	35.7	55.7***	42.9	n.s.
Children	42.4	39.0	34.3	35.7	32.9	n.s.
Alcohol	98.3	98.3	91.4	88.6	97.1	n.s.
X-Rays	40.7	61.0**	35.7	64.3***	65.7***	n.s.
Pesticides	64.4	74.6	54.3	67.1*	64.3***	*
High-voltage transmission lines	55.9	62.7	42.9	62.9**	57.1*	n.s.
Electricity distribution lines	32.2	49.2**	32.9	51.4***	47.1**	n.s.
Electric blankets	17.0	44.1***	11.4	47.1***	27.1**	*
Hair dryers	5.1	25.4***	4.3	38.6***	15.7**	**

[a] Significance test comparing the control group with the 1993 posttest group (see Fig. 1).
* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.

Table IX. Beliefs About Effects of Electromagnetic Fields on Mechanical and Biological Systems

	Moderate or strong interference (%)					
	1990 study		1993 replication		Control group	Pretest effect[a]
	Pretest	Posttest	Pretest	Posttest		
Human nervous system	40.7	52.5	30.0	51.4**	44.3	n.s.
Television signals	57.6	57.6*	51.4	54.3	45.7	n.s.
Radio signals	64.4	55.9**	57.1	50.0	40.0	n.s.
Household smoke detectors	15.3	18.6	5.7	18.6*	11.4	*
Microwave ovens	27.1	27.1	12.9	35.7**	34.3*	n.s.
Weather satellites	40.7	32.2	32.9	35.7	28.6	n.s.
Human digestive system	23.7	25.4	8.6	34.3***	22.9	*
Animal migratory patterns	32.2	33.9	20.0	34.3*	22.9	n.s.
Thinking and problem solving	27.1	28.8	10.0	25.7**	12.9	n.s.
Human immune system	22.0	47.5	20.0	40.0***	35.7	n.s.
Growth of plants	27.1	23.7	25.7	32.9	35.7	n.s.
Spread of diseases	18.6	33.9	17.1	27.1*	17.1	n.s.
Mental health	40.7	50.9	21.4	34.3	21.4	n.s.
Cell growth and reproduction	37.3	49.2	32.9	51.4**	44.3	n.s.

[a] Significance test comparing the control group with the 1993 posttest group (see Fig. 1).
* $p<0.05$.
** $p<0.01$.
*** $p<0.001$.

Table X. Beliefs About EMF's as the Cause of Health and Behavior Disorders

	Somewhat or very possible (%)					
	1990 study		1993 replication		Control group	Pretest effect[a]
	Pretest	Posttest	Pretest	Posttest		
Heart attacks	39.7	32.7	22.9	28.6*	18.6	n.s.
Premature senility	25.9	31.0	21.4	34.3*	25.7	n.s.
Ulcers	27.5	32.8	14.3	28.6*	15.7	n.s.
Fainting spells	25.9	19.0*	25.7	30.0	20.0	n.s.
Mental illness	36.9	37.9	22.9	42.9**	25.7	n.s.
Gang violence	20.7	13.8	10.0	8.6	5.7	n.s.
Cancer	60.4	77.6	60.0	71.4*	64.3	n.s.
Amnesia	22.4	17.2	8.6	22.9	15.7	n.s.
Birth defects	65.5	63.8	48.6	58.6*	61.4	n.s.
Hallucinations	24.6	22.4	15.7	30.0*	5.7	**
Chronic depression	37.9	56.1*	27.1	42.9**	24.3	n.s.
Random street crime	22.4	15.5	10.0	10.0**	4.3	*
Sterility	39.7	46.6	38.6	50.0*	37.1	n.s.

[a] Significance test comparing the control group with the 1993 posttest group (see Fig. 1).
* $p<0.05$.
** $p<0.01$.

brochure, were significant only for microwave ovens. A pretest sensitization effect was observed for household smoke detectors and human digestive system. Again, these comparisons are less powerful than the within-subjects comparisons, suggesting that perceptions of interference of EMF on biological and mechanical systems are less powerful than the other sources of interference shown in Table VIII.

3.5. Electromagnetic Fields and Health Disorders

Subjects were asked to indicate their beliefs about the possible effects of electromagnetic fields on a number of health and behavior disorders that occur to people. For each of 13 disorders, they rated "how possible you think it is that electromagnetic fields may be an important cause of the disorder." Ratings ranged from 1 = "not possible" to 4 = "very possible." Intermediate values were 2 = "slightly possible" and 3 = "somewhat possible." Table X summarizes these ratings.

For the 1990 study, the high pretest ratings were for cancer and birth defects. Though the mean rating for cancer increased after reading the brochure, it did not achieve statistical significance. However, the mean rating for chronic depression did increase significantly.

The 1993 replication group had the same pattern of pretest ratings, with cancer and birth defects higher than the remaining items. However, after reading the brochure all but three of the items showed significantly increased ratings. A small (and unexplainable) pretest effect occurred for hallucinations and random street crime. None of the control group comparisons were significant. It appears that the effects of both the pretest and the brochure on posttest ratings were only strong enough to be observed by within-subjects comparisons. Still, many of the changes in health effect ratings seen in the 1993 replication group are associated with health and physiological effects discussed in the EMF brochure (e.g., heart rate, cancer, birth defects, chronic depression).

3.6. Attitudes Toward Policy Options

Nine questions inquired about policy-related measures for dealing with exposure to electromagnetic fields. Each measure was rated on a scale that ranged from 1 = "strongly against" to 4 = "strongly in favor." Table XI summarizes these responses. Of the nine measures, "do nothing" was the least popular, with only about 10–20% of the respondents expressing support, depending on group. The two measures having the most direct impact on exposure reduction, *put all high-voltage transmission lines underground* and *ban electrical appliances that produce high EMF*, received only moderate support. However, six of the measures were rather strongly supported, with endorsements by over 90% of the respondents in many cases. These were *support further research, require warning labels, begin public in-*

Table XI. Attitudes Toward EMF Policy Options

	Favor or strongly favor (%)					
	1990 Study		1993 Replication		Control group	Pretest effect[a]
	Pretest	Posttest	Pretest	Posttest		
Do nothing at the present.	8.5	10.2	17.1	18.6	14.3	n.s.
Require manufacturers of electrical appliances to provide shielding against electromagnetic field exposure, at an additional cost to consumers.	72.9	69.5	61.4	51.4	57.1*	n.s.
Remove all existing above ground high-voltage transmission lines and put them underground, at an additional expense to households.	44.1	35.6	40.0	40.0	25.7	*
Require manufacturers of electrical appliances to put warning labels on their products to make consumers aware of possible health risks from electromagnetic fields exposure.	94.9	98.3	94.3	91.4	87.1	n.s.
Require utility companies to provide on request free measurements of electrical and magnetic fields in homes and offices.	96.6	89.8	95.7	91.4	84.3	n.s.
Begin a public awareness program to inform the public of the potential health risks of exposure to electromagnetic fields.	96.6	96.6	92.9	91.4	88.6*	n.s.
Ban electrical appliances that can result in particularly high exposure to electromagnetic fields, such as electric blankets.	44.1	45.8	45.7	42.9	21.4**	**
Continue supporting research on effects of electromagnetic fields.	100.0	98.3	97.1	95.7	90.0	n.s.
Require utility companies to put signs on electric power line poles and supports warning the public of the possible health risks of exposure to electromagnetic fields.	84.8	91.5	87.1	87.1	85.7	n.s.

[a] Significance test comparing the control group with the 1993 posttest group (see Fig. 1).
* $p<0.05$.
** $p<0.01$.

formation campaign, require power-pole warning signs, require utility-sponsored EMF measurements, and *require appliance shielding.*

None of the nine measures showed a significant change in mean level of support from first to second administrations, for either the 1990 study or the 1993 replication. However, a significant difference was observed between the control group and the 1993 pretest for four of the measures: *require appliance shielding, put transmission lines underground, begin public awareness program,* and *ban high-EMF appliances.* A significant pretest sensitization effect also appeared for the measures regarding undergrounding transmission lines and banning high-EMF appliances. Most of this effect is accounted for by the relatively weak endorsement of these two items by respondents in the control group compared to other groups of respondents in the study (25 vs. 40%). Why endorsement of these two items was particularly low for the control group is unclear. On the whole, however, respondents' reactions to the policy-related measures they were asked to evaluate was generally in the direction of a desire for exposure reduction through appliance shielding, increased public awareness through appliance/power pole warning labels and utility outreach programs, and continuation of research on electromagnetic fields.

4. DISCUSSION

The results of this study are quite consistent with the earlier findings by Morgan *et al.*[12] Exposure to a brochure designed to provide information about the present state of knowledge regarding health risks of electric and magnetic fields significantly increased people's concerns about those risks. Concerns were relatively low for most sources of exposure to fields, prior to reading the brochure. Large power lines were an exception, showing moderate concern prior to the brochure. Subsequent to reading the brochure our respondents expressed the following:

- higher perceived risk from sources of EMF exposure,
- greater dread (particularly regarding power-line risks),
- greater perceived control over these risks,
- less perceived equity, and
- greater concerns regarding effects of EMF on the nervous system, the immune system, cell growth and reproduction, chronic depression, and cancer.

If this were the first study to find increased concern subsequent to provision of information about electric and

magnetic fields, it would be tempting to attribute the effect to specifics of content. (For example, the brochure's summary statement says "Possible risks of concern include cancer." This might be interpreted as meaning that there is reasonable evidence for a link between electromagnetic fields and cancer.) However, the brochure is careful to emphasize the lack of any current scientific basis for implicating electric and magnetic fields with health effects, as the following examples illustrate.

> A lot of good scientific research has now been done. However, because the biological effects of fields are complicated and still not fully understood, answers to simple questions about whether there are risks are not straightforward. (p. 1)

> While all of these effects may prove significant for our eventual understanding of how fields affect cells, it is important to understand that some of the experiments involve conditions that are very different from those that occur when people are exposed to fields. (p. 6)

> The number of people in these studies who were exposed to the strongest fields is small. This increases the chance that the results are due to coincidence rather than to a real association between field exposure and cancer. Such uncertainty, and the resulting debate about the meaning of data, are fairly common occurrences in epidemiological studies. Resolution of these issues will require more and better data. (p. 8)

> Earlier studies of (the effects of EMF's from electric blankets used during pregnancy) have been suggestive but have involved too few women to allow reliable conclusions. (p. 9)

> It is not clear what aspect of 60 Hz fields (if any) poses a risk. There is evidence that suggests that across the range of field strengths commonly encountered by people, stronger fields may not pose greater risks than weaker fields. (p. 16)

Therefore, coupling these results with the similar findings by Morgan *et al.*[12] suggests that even careful presentation of the current "complicated" (p. 16) state of affairs will increase people's concerns.

Although the reasons for increased perceptions of risk subsequent to reading the brochure are not fully apparent, psychological research on human inference provides some clues to possible mechanisms underlying these results. One possible explanation is an availability effect, whereby mention of a hazard makes it more memorable, more imaginable, and more probable.[10] Thus, for example, the brochure states that

> there is some reason to think that field exposure might be involved in chronic depression . . . However, there is so little evidence about these effects that, at this point, such arguments are really just speculation. (p. 9)

Subsequent to reading this material, the perceived link between electromagnetic fields and chronic depression increased sharply (see Table X).

Whether increased concern is good or bad depends in part on the ultimate message science will bring about health effects of EMF exposure and in part on the longer-term goals for risk communication in this difficult area. Certainly, a high level of concern is uncomfortable for people, particularly when there is great uncertainty about the meaning of EMF exposure for public health. For risk managers and risk communicators who seek to foster a low level of public concern until all the answers are in, brochures and other materials like those studied here are unlikely to achieve that goal. On the other hand, the EMF problem may be with us for a long time before science is able to provide the answers that risk managers and policy makers need to implement technical changes that will alter the public's exposure to EMF. If the public is to become an effective partner in future decisions about EMF health and safety issues, they will need to become informed and aware of the state of the science.[13] Though initial awareness of the science associated with EMF health and safety research may bring an elevation of concern, that concern may leave in its wake a public better prepared to deal with uncertainties about EMF exposure and consequences.

On the other hand, for risk communicators who look to science for a paradigm of risk communication, there is a discomforting message from the results of the studies presented here. Respondents did not appear to discount the credibility of a purported finding according to the weakness of the evidence. This is consistent with studies of the representativeness heuristic[14] and other judgment research[15,16] showing that people are not naturally inclined to discount a finding based upon unreliable evidence and that people respond to new evidence in ways that depend upon their personal beliefs.[17] "Belief-confirming evidence" may be regarded as relatively more valid than evidence that does not mesh with one's prior view.

Our respondents appear to have held personal theories that predisposed them to expect harm from electric and magnetic fields, thus causing them to become more concerned when presented with speculative arguments. Thus, the contrasting, and often equivocal, viewpoints of scientists who express honest disagreements about issues of fact are incorporated into public sentiments about EMF (and, potentially, other technological risks) more on the basis of perceived relevance than on the basis of scientific reliability. To a lay audience, scientific discussions that center around disagreement are potentially more likely to appear as an absence of understanding.

In such an information environment, resort to personal theories can readily dominate lay interpretation of scientific controversy and lead to the selective incorporation of "facts" into naive theories about how EMF exposure translates into actual health effects.

Naive theories about the effects of EMF exposure can come from a number of sources, including both personal experience and cultural themes embodied by images of electric and magnetic fields causing perturbations to otherwise "normal" forms of life. We find in the results from this study support for a pattern of intuitive reasoning based on what we call an "interference model."[6] This model relies on a combination of technical information and naive conceptions of biological functioning, whereby the natural electrical activity in the body is "intefered" with by EMF exposure, much in the same way as a television might be interfered with by an electrical appliance. The intuitive extension of this concept coupled with existing scientific uncertainty about EMF health effect mechanisms as presented in the brochure lead to conclusions about EMF exposure impacts that encompass a broad range of human neurological, biological, and psychological effects. Reasoning of this type is found elsewhere in studies of cognitive psychology that have explored the mental strategies people use to make predictions or draw conclusions, both in general[18] and in particular concrete areas such as physics and biology.[19] How such images figure into the concerns people have about EMF exposure is difficult to gauge. However, it is very likely that the greater the level of scientific uncertainty about EMF health effects, the more likely concerns about EMF exposure will be driven by highly imaginative, though technically inaccurate, notions of the mechanisms by which EMF exposure causes harm.

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[6] The interference model is illustrated by the following quote from a focus group participant discussing EMF. "I think of it as interfering in the electrical processes that you have to have in your body to stay alive. And what is it—just slowing messing things up, causing people to have a heart attack for no apparent reason? Alzheimer's disease, is there something on a similar basis, because all of the electricity in the air is messing up the impulses in your brain."

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