Household Adjustment to Earthquake Hazard: A Review of Research

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Environment and Behavior 2000; 32; 461

DOI: 10.1177/00139160021972621

HOUSEHOLD ADJUSTMENT TO EARTHQUAKE HAZARD
A Review of Research

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ABSTRACT: Data from 23 studies confirm theoretical predictions that households' adoption of earthquake hazard adjustments is correlated with their perceptions of the hazard and alternative adjustments, demographic characteristics, and social influences. However, some findings require modification of existing theories of hazard adjustment. Examination of the methods used in previous investigations underscores a need for better theories, more complete testing of existing theories, and improved data analytic and data reporting procedures in future tests of those theories.

Seismic risk has become an increasing concern since the 1971 San Fernando earthquake. Government at all levels has attempted to reduce vulnerability, but households also must act to limit casualties, property damage, and social/economic disruption. One obstacle to improving seismic safety has been a limited understanding of the process by which households decrease vulnerability. This process, hazard adjustment, encompasses actions that intentionally or unintentionally reduce risk from extreme events in the

AUTHORS' NOTE: *This work was supported by the National Science Foundation under Grant BCS-9633594. None of the conclusions expressed here necessarily reflect views other than those of the authors.* *Correspondence should be directed to Michael K. Lindell, Hazard Reduction & Recovery Center, Texas A&M University, College Station, TX 77843-3137.*

ENVIRONMENT AND BEHAVIOR, Vol. 32 No. 4, July 2000 461-501

natural environment (Burton, Kates, & White, 1978; Moore, 1964). Pre-impact adjustments include hazard mitigation, emergency preparedness, and insurance purchase. Hazard mitigation provides passive protection at impact (e.g., strapping water heaters to walls before an earthquake prevents property destruction). Emergency preparedness supports active response after impact (e.g., establishing supplies of bottled water and canned food before an earthquake allows people to survive disruption to food distribution). Insurance purchase redistributes the financial impact of damage across time and persons.

Many studies in the past 25 years have related respondents' adoption of seismic hazard adjustments to risk perception, demographic characteristics, personal experience, social influence, and other variables. The theoretical constructs, measured variables, and research designs of those studies have varied considerably. The profusion of approaches has yielded a wealth of new and useful ideas, but the idiosyncratic nature of many studies has impeded summarization of this work.

A search of psychological and sociological abstracts identified 23 English-language studies published between 1974 and 1998 that correlated household seismic adjustments with other variables or reported data permitting such correlations to be determined (see Table 1). The next section examines these studies in terms of four methodological issues—vulnerability to random and systematic sampling errors and to random and systematic response errors. This section is followed by a summary of empirical findings regarding four classes of variables—risk perceptions, perceived adjustment attributes, demographic characteristics, and other variables. The empirical findings are followed by an evaluation of the congruence between these empirical findings and theoretical models and suggestions for future research.

METHODOLOGICAL ISSUES

Random sampling errors. The magnitude of random sampling errors in these studies generally is small because, as Table 1 indicates, only six studies had as few as 100 to 250 respondents, three had sample sizes of 251 to 500, and the remaining 14 studies each had more than 500 respondents. Statistical power analysis (e.g., Bailey, 1971) shows that even the smallest of these studies has excellent power (π = .95) to detect a population value of r = .20, whereas studies with N > 400 have excellent power to detect a population

(text continues on p. 468)

TABLE 1
Summary of Study Authors, Location, Sample Size, Design, and Reported Correlates of Seismic Hazard Adjustment

Study	*Study Location (sample size)*	*Study Design*	*Demographic Characteristics*	*Risk Perceptions*	*Adjustment Attributes*	*Other Variables*	*Seismic Adjustments*
Jackson and Mukerjee (1974)	San Francisco (n = 120 residents)	Cross-sectional survey		Expected damage	Spontaneously mentioned attributes		Spontaneously mentioned adjustments
Jackson (1977, 1981)	Los Angeles, CA; Anchorage, AK; Vancouver and Victoria, British Columbia (n = 302)	Cross-sectional survey	Education, income	Expected damage (*ns*)		Prior losses, hazard salience	Spontaneously mentioned adjustments
Sullivan, Mustart, and Galehouse (1977)	San Mateo County, CA (n = 1,400)	4-wave longitudinal survey					Insurance purchase
Kunreuther et al. (1978)	California (n = 1,006)	Cross-sectional survey		Damage probability and cost			Insurance purchase
Turner, Nigg, and Paz (1986); see also Nigg (1982) and Turner (1983, 1993)	Los Angeles County, CA (Wave 1: n = 1,450) (Waves 2-5: $516 \le n \le 551$)	5-wave longitudinal survey	Age, income, education, children in the household, marital status, ethnicity	Proximity to fault, member of endangered group, earthquake fear, earthquake probability		Hazard salience, meeting attendance, fatalism, community bondedness	16 mitigation and preparedness actions

(continued)

TABLE 1 Continued

Study	*Study Location (sample size)*	*Study Design*	*Demographic Characteristics*	*Risk Perceptions*	*Adjustment Attributes*	*Other Variables*	*Seismic Adjustments*
Kiecolt and Nigg (1982)	Same as above	Same as above	Same as above	Proximity to fault, member of endangered group, earthquake fear, earthquake probability		Objective risk factors, community attachment, fatalism, information seeking, insurance, preparedness	Outmigration intention
De Man and Simpson-Housley (1987)	Sunnyvale-Alviso, CA (*n* = 130)	Cross-sectional survey		Expected damage			Unspecified number of adjustments
Davis (1989)	San Bernardino, Long Beach, and Whittier, CA (*n* = 244)	Cross-sectional survey			Perceived effectiveness, cost/effort, awareness, required knowledge	Behavioral intentions	10 mitigation and preparedness actions
Garcia (1989)	Irvine, CA (*n* = 476)	Cross-sectional survey			Perceived effectiveness		15 mitigation and preparedness actions

Palm, Hodgson, Blanchard, and Lyons (1990)	Contra Costa, Santa Clara, Los Angeles, and San Bernardino, CA (*n* = 1,786)	Cross-sectional survey	Education, percentage of net equity, age of household head, age of structure, children in home, aged in home, home value	Damage probability and cost	Need, cost		Insurance purchase
Mulilis, Duval, and Frequency of Lippa (1990)	12-item mitiga- (*n* = 242)	Los Angeles, CA panel and longitudinal survey		11-wave		adjustment evaluation	tion and preparedness scale
Mulilis and Lippa (1990)	Orange County, CA (*n* = 111)	Cross-sectional field experiment		Event probability and severity	Response efficacy	Self-efficacy	12-item mitigation and preparedness scale
Palm and Hodgson (1992)	Santa Clara and Contra Costa, CA (*n* = 1,071)	2-wave longitudinal survey				Experienced damage in recent earthquake	Insurance purchase
Dooley, Catalano, Mishra, and Serxner (1992)	Orange County, CA (*n* = 1,641)	4-wave longitudinal survey	Marital status, children, age, neighborhood tenure	Hazard concern		Earthquake experience	5 emergency preparedness actions

(continued)

TABLE 1 Continued

Study	*Study Location (sample size)*	*Study Design*	*Demographic Characteristics*	*Risk Perceptions*	*Adjustment Attributes*	*Other Variables*	*Seismic Adjustments*
Mileti and O'Brien (1992)	Santa Cruz, CA (n = 918); San Francisco, CA (n = 734)	Cross-sectional survey	Gender	Perceived aftershock probability		Prior adjustments; number and quality of messages	6 mitigation and preparedness actions
Mileti and Fitzpatrick (1992, 1993)	Coalinga, CA (n = 347); Paso Robles, CA (n = 357); Taft, CA (n = 234)	Cross-sectional survey		Expectation of earthquake in next few years		Prior adjustments, information seeking/receipt; observation of others, message specificity and consistency, source credibility	12 mitigation and preparedness actions
Edwards (1993)	Memphis, TN (n = 544)	2-wave longitudinal survey	Education, income, ethnicity, children				14 mitigation and preparedness actions
Showalter (1993)	New Madrid and East Prairie, MO; Marked Tree and Wynne, AR (n = 303)	Cross-sectional survey		Threat of death or injury			4 items: meeting attendance, mitigation, preparedness, and insurance
Farley, Barlow, Finkelstein, and Riley (1993)	St. Louis, Cape Girardeau, and Sikeston, MO (n = 583)	Cross-sectional survey		Event likelihood		Proximity to fault, adjustment intentions, fatalism	4 items: meeting attendance, mitigation, preparedness, and insurance

Mulilis and Duval (1995)	University of Southern California students (n = 135)	Cross-sectional field experiment		Event probability, severity, and immediacy	Response efficacy	Protection responsibility	12-item mitigation and preparedness scale
Russell, Goltz, and Bourque (1995)	Whittier Narrows, CA (191 high impact area/499 low impact area) Loma Prieta, CA (205 high impact area/451 low impact area)	Cross-sectional survey	Home ownership, neighborhood tenure, income, education, past experience		Utility for other purposes		17 mitigation and preparedness actions
Mileti and Darlington (1995, 1997)	San Francisco Bay area (n = 806)	Cross-sectional survey with retrospective pretest	Income, gender, race, education, age, occupation	Expectation of earthquake in next few years; earthquake concern		Prior adjustments, number of media channels monitored, number of information sources contacted, observations of others, message consistency	18 mitigation and preparedness actions
Bourque, Shoaf, and Nguyen (1997)	Los Angeles (n = 1,900)	Longitudinal survey	Immigrant status				11 mitigation and preparedness actions

value of $r = .10$. Because $r = .10$ corresponds to an explained variance of only 1%, it seems unlikely that anyone would regard a correlation smaller than this as practically significant, even if statistically significant. Accordingly, one can rule out inadequate sample size as an explanation for any failure to confirm a theoretical prediction or replicate a previous correlation having a practically significant value of $r = .10$.

Systematic sampling errors (sample bias). Consistent with Sudman (1983), most researchers have collected data from a broad range of risk area residents. Random digit dialing (telephone interviews) and sampling from a list of residential addresses (mail questionnaires) are typical procedures. The number of recontacts has ranged from 0 to 12, leading to substantial variation in response rates. A low response rate makes the sample's representativeness uncertain because nonresponse might be systematic rather than random. Specifically, those who have undertaken few adjustments might be less likely to return a questionnaire. If so, underresponse would upwardly bias the estimated prevalence of seismic hazard adjustment in the population. Researchers often are advised to assess sample bias by determining if the respondents' demographic characteristics are similar to census data for that location. Only nine of the studies in Table 1 have reported such comparisons, but there are four reasons for believing that this omission does not constitute a significant obstacle to drawing conclusions about correlates of seismic adjustment.

First, a low response rate implies bias in a sample's demographic characteristics only if demographic categories are significantly correlated with questionnaire response. Second, a sample that is biased in terms of its demographic characteristics will also be biased in terms of other variables such as seismic adjustment and its antecedents only if such variables are significantly correlated with demographic characteristics (cf. Bohrnstedt, 1983). These two considerations are illustrated by the similarity in the results of a telephone survey (Garcia, 1989) and a mail survey (Davis, 1989) reporting frequencies of adoption for almost identical sets of seismic adjustments. Both studies were based on locational sample frames. However, Garcia (1989) reported an 84% response rate and the respondents' demographics matched those of the jurisdiction, whereas Davis (1989) reported only a 28% response rate and, compared to census data, was higher in age, education, and income, underrepresented Hispanics, and overrepresented Asians. Despite these demographic differences, Davis's data yielded higher estimates of adoption on only 7 of the 10 seismic adjustments common to the two studies, and his average adoption rate, $\overline{p} = .63$, was only 6 percentage points more than Garcia's average adoption rate of $\overline{p} = .57$. Moreover, data in the next section indicate that demographic characteristics have small correlations with seismic adjustment and its antecedents. Thus, even demonstrated bias in a sample's demographic characteristics is uninformative about the prevalence of adjustment adoption and its antecedents.

Third, even if there is bias in the estimated means and proportions on seismic adjustment and its antecedents, there will be little effect on correlation coefficients unless there are "ceiling" or "floor" effects that cause the correlation coefficients to be systematically underestimated. Finally, even if sample bias has caused a modest degree of variance restriction and, thus, slight downward bias in the correlation coefficients, the large sample sizes and consequent power of the study designs reviewed here make it is unlikely that practically significant correlations (i.e., $r = .10$) have been overlooked.

Of course, these arguments do not imply an endorsement of convenience samples such as college student subject pools, which are likely to be uniformly low in seismic adjustment and its antecedents. Such homogeneous samples yield small variances on the dependent and independent variables, biasing correlations downward. Consequently, convenience samples may be quite limited in their ability to identify correlates of seismic adjustment. However, even differences between the best response rates from telephone surveys and the worst response rates from mail surveys appear to be of relatively little consequence for estimating the prevalence of seismic adjustment and its antecedents. Such differences are likely to have no impact on correlations between seismic adjustment and its antecedents as long as locational sample frames are used.

Systematic response errors (response bias). Concern sometimes is expressed that reporting bias, as opposed to the sampling bias addressed in the previous section, will produce inflation in respondents' self-reports of their adoption of (socially desirable) seismic adjustments. If all respondents inflate their self-reports of adjustment adoption by a constant, means and proportions will be overestimated but correlation coefficients will be unaffected. Inflation by a variable amount across respondents will add error and bias correlations downward. Thus, reporting bias should be of minimal concern in evaluating correlations between seismic adjustment and its antecedents.

A more significant threat to the validity of inferences about correlations between seismic adjustment and its antecedents arises from measuring both sets of variables in the same questionnaire. The possibility that common-method variance has contaminated correlations among the measures can be ruled out if there is evidence of discriminant validity among the constructs in the questionnaire. Discriminant validity is confirmed if there are pairs of variables (e.g., two different attitudinal variables) that have high reliabilities but nonetheless have nonsignificant correlations (Campbell & Fiske, 1959). Unfortunately, no attempts have been made to address this issue in any studies of seismic adjustment. One could evaluate these studies post hoc if the authors had reported the complete matrix of intercorrelations among variables, but Mileti and Darlington (1997) are the only researchers to have done so. The large number of near-zero correlations in their data suggest that common-method variance was not present, but the lack of comparable data in the other studies precludes any more general conclusions about the presence of this artifact.

Random response errors (unreliability). Researchers are advised to reduce the impact of random variance in their measures by summing across multiple items and to report a numerical estimate of each measure's reliability. Unfortunately, few studies of seismic adjustment have used multi-item scales and fewer still have reported their measures' reliabilities. Sixteen of the 23 studies in Table 1 have used multi-item scales to measure seismic adjustment, but only limited reliability data have been reported. The Mulilis-Lippa Earthquake Preparedness Scale is reported to have internal consistency reliabilities ranging from $\alpha = .68$ to $\alpha = .97$ and test-retest reliabilities ranging from $r = .84$ to $r = .94$ (Mulilis, Duval, & Lippa, 1990). Russell, Goltz, and Bourque's (1995) factor analysis of seismic adjustment items revealed three subscales: survival ($\alpha = .73$ and .69 for the Whittier Narrows and Loma Prieta subsamples, respectively), planning, ($\alpha = .42$ and .43), and hazard mitigation ($\alpha = .44$ and .53). Unanswered questions about reliability are even more prevalent among predictors of seismic adjustment. These have been measured by single items that, with the exception of the demographic variables, are of uncertain reliability. However, as noted above, the correlations reported in these studies are based on such large sample sizes that they have substantial statistical power. Thus, the magnitudes of the correlations might be underestimated but it is unlikely that important antecedents of seismic adjustment have been overlooked altogether because of attenuation due to unreliability.

Selective reporting. Assessment of the average magnitude of the correlations between seismic adjustment and its potential antecedents is frustrated by researchers' tendency to report only those variables having statistically significant correlations. This selective reporting also makes it difficult to interpret the failure to report a significant correlation of a variable with seismic adjustment adoption; it could be either that the variable was measured but nonsignificant or that the variable was not measured at all. Consequently, an average (across studies) of the reported correlations almost certainly would overestimate the true correlation.

Causal direction of correlations with risk perception. All but one of the studies in Table 1 contain an important deficiency identified by Weinstein and Nicolich (1993), who found an apparent contradiction underlying the logic of correlations between risk perceptions and seismic adjustment. On one hand, negative correlations are expected between risk perception and hazard adjustment if respondents accurately recognize that low levels of hazard adjustment cause high levels of vulnerability. On the other hand, positive correlations are expected between risk perception and hazard adjustment if respondents act on the belief that high levels of hazard vulnerability warrant high levels of hazard adjustment. Weinstein and Nicolich (1993) resolved the contradiction by recognizing that positive correlations actually should be expected between risk perception and behavior change, not between risk perception and currently adopted adjustments. Consequently, they recommend longitudinal designs for assessing correlations between risk perception and subsequent adoption of adjustments. They also observe that appropriate inferences can be drawn from cross-sectional designs but only after calculating partial correlations to hold the effects of past adjustment adoption constant. They caution that even partial correlations might be downward biased if risk area residents have had time to adopt adjustments, and cross-sectional designs are vulnerable to the possibility that perceptions have been distorted to justify existing behavior (i.e., display the common-method variance described in a previous section).

None of the studies in Table 1 conducted the analyses advocated by Weinstein and Nicolich (1993) but one study provided enough data for a post hoc analysis. Mileti and Darlington's (1997) design incorporated a self-report of recent adjustments and a retrospective report of adjustments adopted prior to a hazard awareness campaign. A retrospective pretest could be affected by recall biases, but the researchers' table of pre- and post-brochure frequencies of adoption for each individual adjustment strongly differentiates among the adjustments and across the two points in time. Thus, the pre- and post-campaign measures of adjustment appear to be independent measurements. Data from Mileti and Darlington's (1997) correlation matrix permit the effect of the pre-campaign adjustments to be partialed out of the correlations between antecedent variables and post-campaign adjustments. This analysis reveals that none of Mileti and Darlington's (1997) conclusions need to be changed, but the fact that one study's conclusions are unaffected does not mean that this also is true of all other studies of seismic adjustments.

EMPIRICAL FINDINGS

The next section examines the measures used to operationalize seismic adjustment, and the following sections summarize empirical findings regarding the correlations of four classes of variables—risk perceptions, perceived adjustment attributes, demographic characteristics, and other variables. These empirical findings are followed by an evaluation of the congruence between these empirical findings and theoretical models and the suggestion of future research directions.

SEISMIC ADJUSTMENT

Measures of seismic adjustment. As Table 1 indicates, there has been substantial variation across studies in the measures of seismic adjustment employed. One study (Jackson & Mukerjee, 1974) used a free-response method to assess respondents' awareness of seismic adjustments. Four studies examined insurance purchase alone, whereas the remaining studies used a variety of composites of hazard mitigation measures, emergency preparedness actions, and insurance purchase. As noted earlier, a composite measure of seismic adjustment is strongly recommended, but variation in the component items across studies is problematic. Any studies that included only adjustments with low popularities would restrict the variance in the dependent variable and attenuate the correlations of antecedent variables with seismic adjustment. The extent to which this has occurred cannot be determined because, with few exceptions (Mileti & Darlington, 1997; Russell et al., 1995; Turner, Nigg, & Paz, 1986), researchers investigating the correlation of seismic adjustment with antecedent variables have not reported scale variances or item popularities.

Prevalence of seismic adjustment. Seismic adjustment appears to have increased over time. Twenty-five years ago, estimates of the percent of risk area residents undertaking any seismic adjustments ranged only from 18% (Endo & Neilsen, 1979) to 31% (Jackson, 1977, 1981). Jackson's (1977, 1981) finding that only 1% had made structural modifications to their homes is lower than the 8% reported by Jackson and Mukerjee (1974), but the disparity is within sampling fluctuations. Jackson and Mukerjee (1974) also reported that insurance had been adopted by only 8% of their respondents, a figure consistent with Sullivan, Mustart, and Galehouse's (1977) estimate of insurance purchase by 5% of their 1970 Northern California sample. Sullivan and his colleagues found that insurance purchase had increased to 22% in

1976—possibly due to the San Fernando earthquake. The latter figure is compatible with the 33% estimate later reported in the same area (Palm, Hodgson, Blanchard, & Lyons, 1990). Still later surveys in Southern California reported rates of insurance purchase ranging from 26% (Garcia, 1989) to 45% (Davis, 1989). Differences between the latter two estimates might be due to the fact that Davis (1989) collected data in areas of greater seismic vulnerability.

The relative popularity of different seismic adjustments seems to be consistent across studies. Garcia (1989) and Davis (1989) reported the popularities of 10 seismic adjustments common to the two studies. Although there were some significant differences in the absolute levels of adjustment adoption (e.g., 80% of Garcia's sample reported knowing how to shut off utilities but only 68% of Davis's sample did so), the two sets of percentages were highly correlated ($r = .77$, $p < .01$).

PERCEIVED RISK

Measures of perceived risk. Risk perceptions have been measured in a number of different ways. One study used free-response methods to assess respondents' risk perceptions (Jackson, 1977, 1981). Other researchers have measured respondents' global risk perceptions by asking them whether residents of their city "have trouble" with earthquakes (Jackson & Mukerjee, 1974) or by asking them to rate their level of concern about the hazard (Dooley, Catalano, Mishra, & Serxner, 1992). Risk perceptions also have been measured more specifically in terms of characteristics of the event such as the probability and severity (Mulilis & Lippa, 1990) and imminence (Mulilis & Duval, 1995) of an earthquake. Specific risk perceptions also have been measured in terms of personal consequences, especially the probability and cost of property damage (Kunreuther et al., 1978; Palm et al., 1990). Other important personal consequences include personal death or injury, property loss, interference with work, and social disruption (Showalter, 1993).

Prevalence of risk perceptions. Even early studies showed that respondents were aware of the potential for earthquakes in their vicinity. Sullivan et al. (1977) found that the majority (77% in both their 1970 and 1976 surveys) were aware of a fault's location within 1 mile of their homes, and most (72% in 1970 and 63% in 1976) knew of the fault's location before moving there but said that they would feel no safer (82% and 74%) if they lived 5 miles farther away from the fault. About half (52% and 44%) had felt small tremors in their current residence. In an early demonstration of the distinction between hazard awareness and risk personalization, Jackson and Mukerjee (1974) found that 86% of their respondents had experienced an earthquake, and nearly half (43%) thought another earthquake would occur in the next few years, but only 34% expected to be affected personally. Accordingly, when asked if residents of the city "have trouble" with earthquakes, only 37% agreed. Furthermore, among those expecting damage from a future earthquake, nearly half (49%) expected slight or nonexistent damage or had no clear idea of how much damage that they would incur. By contrast, 20% expected substantial damage and only 7% expected total loss of property. The lack of personalization of the risk was supported by free response data showing respondents' descriptions of earthquakes much more frequently consisted of physical event descriptions (more than 50%) than of affective/fear responses (27%) or personal consequences such as casualties or property losses (15%).

Turner et al. (1986) also reported data showing risk area residents failed to personalize the risk. They found that awareness of the Palmdale Uplift was high and remained relatively stable, with the percentage of respondents who had heard of the uplift rising from 59% in February 1977 to 67% in July 1978 and then dropping to 59% in December 1978. However, only 25% of their respondents could be described as fully aware (having heard, understood, and considered the information personally relevant) in February 1977, with a slight rise to 29% in July 1978, and a drop to 23% in December 1978. Although the causes of the fluctuations observed by Turner et al. (1986) could not be explained, some evidence of the impact of variations in issue salience can be found in longitudinal data reported by Dooley et al. (1992). These researchers found that residents' earthquake concerns rose immediately after each of two significant earthquakes but declined in each case by the time of the following survey. These data suggest that earthquake experience attracts attention, but the increased salience of seismic hazard is short-lived and decays rapidly in competition with more routine demands on risk area residents' attention (see also Pennebaker & Harber, 1993).

Early findings about risk area residents' failure to personalize seismic risk have been firmly supported in subsequent research. Mileti and Fitzpatrick (1993) found that about 80% of their respondents believed that they would experience a Parkfield earthquake, but only about one third thought it would harm them, their families, or their property. Similarly, Mileti and Darlington (1995) found the local population expected an earthquake to strike the area (18% expected one in the next couple years, 48% in the next 5 years) but were optimistic about avoiding personal loss (only 10% expected loss in the next couple of years, 22% in the next 5 years).

Finally, there is evidence that risk area residents consider a broad range of consequences in their definition of personal risk. Showalter (1993) found that residents surveyed before Iben Browning's predicted earthquake date were moderately concerned about risks of death, injury, and income loss but were even more concerned about property damage and loss of services. In a follow-up survey, concerns about property damage and loss of services dropped significantly. However, concerns remained greater about these two impacts than about any of the other three impacts (death, injury, and income loss).

Correlations of risk perceptions with seismic adjustment. These studies generally, but not universally, have found significant correlations between risk perception and seismic adjustment. Jackson (1977, 1981) found adjustment adoption was associated with hazard salience (spontaneous mention of seismic hazard in response to a question about disadvantages of living in their location). Similarly, Turner et al. (1986) found seismic adjustment was significantly related to the level of hazard awareness, with a high level of preparedness being much more likely among those who had heard, understood, and personalized the risk (39%) than among those who had not (19%). Finally, Dooley et al. (1992) reported seismic adjustment was significantly related to another global measure, earthquake concern.

Other researchers have reported correlations between seismic adjustment and more specific measures of risk perception. Kunreuther et al. (1978) found insurance purchase was associated with perceived earthquake likelihood and expected property damage from a severe event; 32% of uninsured residents believed a damaging earthquake had less than a 1% chance of occurring, but only 23% of the insured thought an earthquake was this improbable. Moreover, 12% of the uninsured thought a severe earthquake would cause them no damage, whereas only 2% of the insured thought a severe earthquake would be this inconsequential. Palm et al. (1990) replicated these results by finding that insurance purchase was significantly related to the perceived probability of serious damage from a major earthquake and the expected damage from such an earthquake.

There is evidence that seismic adjustments other than insurance purchase are predicted by specific measures of risk perception. De Man and Simpson-Housley (1987) found that estimates of future earthquake damage were correlated with the number of seismic adjustments adopted. Mileti and O'Brien (1992) found that perception of aftershock likelihood following Loma Prieta predicted a composite measure of seismic adjustment, whereas Mileti and

Fitzpatrick (1992) reported that risk perception significantly predicted seismic adjustment in the Parkfield risk communication experiment. Following the Browning earthquake prediction, Farley, Barlow, Finkelstein, and Riley (1993) reported that adjustment adoption was predicted by greater perceptions of quake likelihood, whereas Showalter (1993) found statistically significant effects of concern about threats of death and injury on all protective responses except insurance purchases. The latter finding is consistent with the expectation that insurance purchase would be more highly correlated with threats of property damage, but such correlations were not reported.

Finally, there have been nonsignificant findings. Russell et al. (1995) found that a high level of concern (i.e., frequent thoughts about earthquakes) significantly predicted earthquake adjustment in only 2 of 12 (17%) of their analyses. Furthermore, Jackson (1977, 1981) found adjustment adoption was unrelated to expectations of future earthquake losses, whereas Mileti and Darlington (1997) reported that adjustment adoption was uncorrelated with risk perception and hazard concern.

ADJUSTMENT ATTRIBUTES

Researchers have repeatedly found differences in the popularity of seismic adjustments (Davis, 1989; Edwards, 1993; Farley et al., 1993; Garcia, 1989; Mileti & Darlington, 1997; Mileti & Fitzpatrick, 1993; Mileti & O'Brien, 1992). However, few attempts have been made to explain why these differences occur, and discussion of adjustment attributes has been limited mostly to post hoc speculation about what might have caused the correlations of risk perception with adjustment adoption to be low. For example, Edwards (1993) attributed the substantial differences in the popularity of seismic adjustments—84% of her respondents had a flashlight and 70% had a battery radio, whereas only 3% secured furniture and 4% had an engineer's assessment or made structural changes—to corresponding differences in the money, time, and effort involved, as well as the utility of these actions as adjustments for other uses.

Measures of adjustment attributes. That so few studies have assessed respondents' perceptions of seismic adjustment attributes is surprising because Fishbein and Ajzen's (1975) theory of reasoned action (TRA) predicts people's behavioral response to a situation (i.e., their seismic adjustments) will be more highly correlated with their beliefs about a behavior (i.e., their perceptions of those adjustments) than with their beliefs about the situation that motivated that behavior (i.e., their risk perceptions). Fishbein and Ajzen (1975) have advocated using free-response methods to identify people's salient beliefs about a behavior in question. Consistent with this recommendation, Jackson and Mukerjee (1974) found that respondents assessed earthquake adjustments in terms of situational appropriateness (e.g., evacuation following total destruction), technological requirements (e.g., personal ability to implement), effectiveness, and cost.

Other studies addressing adjustment attributes have examined only one or two of them. These most frequently were effectiveness (Garcia, 1989; Mulilis & Duval, 1995; Mulilis & Lippa, 1990), cost (Kunreuther et al., 1978; Palm et al., 1990), and utility for other purposes (Russell et al., 1995). Palm et al. (1990) also assessed respondents' perceptions of the need for insurance, but this actually is an indirect measure of risk perception (i.e., a global perception of the threat) rather than a direct measure of an adjustment attribute. The exception is Davis (1989), who assessed perceptions of four attributes—effectiveness, cost/effort, awareness, and required knowledge.

Prevalence of beliefs about seismic adjustments. A common finding of early seismic adjustment studies is many risk area residents' total lack of information about suitable adjustments. Jackson and Mukerjee (1974) found that 45% of their respondents were unaware of any measures to reduce the damages from an expected earthquake. Consistent with this finding, other researchers have reported that a significant proportion of those not purchasing insurance were unaware of its availability (Sullivan et al., 1977 [9% in their 1970 survey and 14% in 1976]; Kunreuther et al., 1978 [25%]). However, Davis's (1989) study suggests that this has changed over the years. For 7 of the 10 adjustments he listed, less than 6% of the respondents reported that the adjustment had not been adopted because of lack of awareness. Even the adjustment that respondents most frequently reported being unaware of, removing heavy objects from the sleeping area, was unfamiliar to only 29% of the respondents.

Of course, awareness of an adjustment does not imply accuracy of risk area residents' beliefs about it. Kunreuther et al. (1978) found that most nonpolicyholders who were aware that insurance coverage was available could not provide an accurate estimate of its cost. A quarter of them were unable to give any estimate of the premium and most of the rest overestimated premium rates. This finding was later replicated by Palm et al. (1990), who reported that 44% of those not purchasing insurance in their study overestimated the cost of premiums by 50% or more.

Correlations of adjustment attributes with seismic adjustment. There is limited but suggestive evidence of correlations between adjustment attributes and seismic adjustment. Sullivan et al. (1977) found that those not purchasing insurance reasoned it was not needed (29% in 1970 and 28% in 1976) or too expensive (59% in 1970 and 42% in 1976). Palm et al. (1990) found that the most frequent reasons for failing to purchase insurance were that it was not necessary (29% of nonpurchasers) or too expensive (54%). These data suffer from two limitations. First, as noted earlier, “lack of necessity” actually is an indirect measure of risk perception. Second, presenting a question about insurance cost only to nonpurchasers precludes the calculation of a correlation. A correlation can be inferred by assuming that no purchaser would describe insurance as too expensive. However, this inference is speculative and must be verified with empirical data.

Further evidence of an association between adjustment attributes and adjustment adoption was reported by Russell et al. (1995), who compared the results of surveys conducted after the Whittier Narrows and Loma Prieta earthquakes with data from an earlier study of the 1971 San Fernando earthquake (Bourque, Reeder, Cherlin, Raven, & Walton, 1973). Russell et al. (1995) asked respondents to report whether they had implemented each of 17 actions, whether the action was implemented before or after the earthquake, and whether the adjustment was specifically for seismic safety or for other reasons as well. The utility of an adjustment for other functions played a significant role in acquiring basic survival tools (raising adoption from 7% to 26%) but had a negligible effect on planning and hazard mitigation activities (raising adoption from 0% to 3%).

The best available data on the association of adjustment attributes with adjustment adoption come from Garcia (1989) and Davis (1989). Garcia (1989) reported the percentages of respondents adopting each of 15 seismic adjustments and also the percentage rating each adjustment as very effective. The large correlation between these sets of percentages ($r = .87, p < .01$) suggests that perceptions of effectiveness are a significant determinant of adoption decisions. This conclusion is further supported by post hoc analysis of Davis’s (1989) data. Effectiveness had the largest correlation with adoption ($r = .57, p < .05$), followed by cost/effort ($r = -.43$, *ns*), and required knowledge ($r = .26$, *ns*). These correlations should be treated cautiously because they are derived from group-level rather than individual-level data. They do, however, suggest that further examination of the role of adjustment attributes is warranted.

DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

Measures of demographic characteristics. Most studies of seismic adjustment have measured demographic characteristics including sex, age, education, income, occupation, marital status, presence of dependents (school-age children or the aged), ethnicity, immigrant status, neighborhood tenure, and home ownership.

Correlations of demographic characteristics with seismic adjustment. Studies in Table 1 report an inconsistent pattern of correlations with seismic adjustment. Turner et al. (1986) found that community bondedness was significantly correlated with a multi-item index of seismic adjustment. Community bondedness was defined as neighborhood tenure, identification of the neighborhood as one's home, participation in community organizations, and the presence of friends and relatives nearby. Community bondedness was correlated with income and school-age children in the home. These results were later supported by Dooley et al. (1992), who reported that the level of seismic adjustment was significantly associated with marital status, presence of children in the household, age, and neighborhood tenure. Edwards (1993) also found correlations of earthquake preparedness activities with multiple demographic characteristics—presence of children at home, higher education, higher household income, and White ethnicity. Finally, Russell et al. (1995) replicated a number of these findings, reporting that adjustment adoption was associated with income, education, home ownership, and neighborhood tenure.

By contrast, Palm et al. (1990) found an inconsistent pattern of associations between household characteristics and insurance purchase. Of the 10 variables measured, only education was significantly correlated with insurance purchase in as many as two counties, and 6 other variables (percentage of net equity, age of household head, age of house structure, children in household, persons older than 65 in household, and estimated home value) were significant in only one county. Net equity as a percent of total net worth, tenure in California, and tenure in the neighborhood were not significantly associated with insurance purchase.

Other studies also have reported that adjustment adoption is related to only a single characteristic—female gender (Mileti & O'Brien, 1992), race (Mileti & Darlington, 1997), educational attainment (Farley et al., 1993), or immigrant status (Bourque, Shoaf, & Nguyen, 1997). Unlike other studies, Mileti and Darlington (1997) reported that education was negatively related to adoption of adjustments following dissemination of a hazard awareness brochure in the San Francisco Bay area. However, they noted that this probably was because education was positively correlated with adjustments undertaken before receiving the brochure. Thus, more highly educated respondents already had adopted many adjustments. Finally, Jackson (1977, 1981) found that adoption of adjustments was unrelated to any demographic characteristics in his study.

These findings suggest that demographic characteristics have small correlations that are statistically significant only in very large samples. Apparent inconsistencies may have arisen from selective reporting of only statistically significant correlations between demographic characteristics and seismic adjustment in the smaller samples. Even with large samples, however, demographic characteristics are more strongly related to multi-item indexes than to insurance purchase alone.

OTHER VARIABLES

Location. A significant correlation of seismic adjustment with location is indicated by significant differences among communities in the prevalence of adjustment adoption. Palm et al. (1990) found that earthquake insurance coverage varied considerably from one community to another. Moreover, Mileti and O'Brien's (1992) study of aftershock warnings following Loma Prieta found many significant differences between Santa Cruz and San Francisco in the rate of adoption of each adjustment. Such findings are difficult to interpret because they reflect an unknown composite of the effects of fault proximity, hazard experience, and social influences. Moreover, the logical problems in making cross-level inferences about one of analysis (the household) from data that have been measured at or aggregated to another level (the community) have long been recognized as an ecological fallacy (Robinson, 1950). Consequently, no useful conclusions can be drawn regarding the effect of location on seismic adjustment.

Fault proximity. Findings regarding seismic fault proximity are inconsistent. Farley et al. (1993) reported that adoption of adjustments was correlated with proximity to the New Madrid fault. By contrast, Palm et al. (1990) and Mileti and Darlington (1997) found no association with proximity to an earthquake fault. This discrepancy may be due to differences in public beliefs about the seismic fault structures in the central United States and California. The Iben Browning prediction emphasized a single fault affecting a large geographic area, whereas the samples for the Palm et al. (1990) and Mileti and Darlington (1997) studies were drawn from an area well-known by risk area residents to have multiple (and presumably less distinctive) fault lines.

Previous seismic experience. A logical source for learning about extreme environmental events is past experience, but there are inconsistent findings regarding its effects. Adjustment adoption has been found to be directly related to the number of earthquakes experienced (Russell et al., 1995), amount of previous earthquake losses (Jackson, 1977, 1981), and experience of earthquake losses by one's self or close others (Turner et al., 1986). Moreover, Dooley et al. (1992) found evidence suggesting that experience of an "earthquake that scared you" indirectly affected seismic preparedness. All of these studies used composite measures of seismic adjustment.

By contrast, Palm and Hodgson's (1992) follow-up study on the impact of the Loma Prieta earthquake reported negligible effects of past experience on insurance purchase. Many of those in the affected counties of Santa Clara and Contra Costa were affected by property damage (53% and 11%, respectively), personally knew someone injured (14% and 11%), or knew someone whose home was damaged in the event (65% and 32%). Countywide rates of insurance purchase increased marginally in the affected counties (11% and 7%), and minimally in the nonimpacted counties of Los Angeles and San Bernardino (6% and 1%, respectively). Impact area residents also increased their adoption of other adjustments to 31% in Santa Clara (a significant increase from the 9% level before the earthquake) and 10% in Contra Costa to higher levels than in the nonimpacted counties of Los Angeles and San Bernardino (6%).

These data led Palm and Hodgson (1992) to conclude that behavior and risk perceptions changed only slightly in the most significantly affected counties and remained stable for the remainder of the sample. Similar results were obtained by Russell et al. (1995), who found that prior experience significantly predicted seismic adjustment in only 1 of 12 analyses (8%) that involved two sites by two occasions by three types of seismic adjustments in a factorial design. Furthermore, Mileti and O'Brien (1992) found small correlations ($r = .01$ in Santa Cruz and $r = .11$ in San Francisco) of prior earthquake experience with Loma Prieta aftershock adjustments, whereas Mileti and Darlington (1997) reported nonsignificant correlations of past damage in the Loma Prieta earthquake with a multi-item index of seismic adjustments.

Social influences. Information derived from others is important because damaging earthquakes occur so infrequently that it is difficult to learn by trial-and-error from personal experience. The studies in Table 1 have examined two sources of social influence—primary groups (friends, relatives, neighbors, and coworkers) and the mass media—and found evidence that both types are associated with seismic adjustment. In an early study addressing primary group influences, Jackson and Mukerjee (1974) concluded that it would not be possible for informal social pressures to have more than a small impact on adjustment adoption because 53% of the respondents either did not know or could not recall how their neighbors had adjusted to earthquake hazard. By contrast, in studies conducted after nearly 20 years of earthquakes, Mileti and Fitzpatrick (1992) and Mileti and Darlington (1997) found that respondents' own adoption of seismic adjustments was indeed significantly correlated with observation of seismic adjustments by others.

Some studies have focused on mass media hazard awareness campaigns and earthquake predictions. Mileti and O'Brien (1992) found that adoption of adjustments immediately after the Loma Prieta earthquake was significantly related to information quality (specificity, consistency, and source certainty) and information reinforcement (number of warnings). Similarly, Mileti and Fitzpatrick (1992) found significant effects for frequency of information receipt, message specificity, and source consistency in their study of the Parkfield prediction. More recently, Mileti and Darlington's (1995, 1997) study of the effects of a hazard awareness campaign in the San Francisco Bay area found that respondents had engaged in a large number of seismic adjustments. Many of these were adopted before the campaign, but even more were undertaken in the following year. For example, emergency equipment storage rose from 50% to 81%, food and water stockpiling increased from 44% to 75%, and earthquake insurance purchases went from 27% to 40%. Mileti and Darlington (1997) reported that adoption of these and other adjustments was correlated with the number of information channels and the presence of response guidance.

There also is evidence that seismic adjustment adoption increases following a warning of an impending earthquake. The Turner et al. (1986) study of Southern California residents' response to a potential earthquake precursor known as the Palmdale Uplift showed that a multi-item index of seismic adjustment varied over a 2-year period. About half (51%) of the respondents could be classified as highly prepared in February 1977 and this rose to 67% in August of that year. One important finding of this study is that changes in seismic adjustment are not always increases; preparedness fell to 56% in January 1978, rose again to 62% in July 1978, and fell again to 57% in December 1978. Similarly, data from Bourque et al. (1997) show increase followed by decline over an 18-year period.

Later, Kunreuther (1993) contended that the Iben Browning earthquake prediction produced a substantial increase in earthquake insurance coverage in the New Madrid Seismic Zone, rising from 12% in 1989 to 37% in 1990. Showalter (1993) also found significant levels of behavioral response to the Browning prediction, with 28% attending meetings or seminars, 50% preparing emergency survival kits, 41% purchasing earthquake insurance, and 20% making physical changes to reduce earthquake damage in their homes. Similarly, Farley et al. (1993) reported that there was a significant increase in household earthquake preparedness between Wave 1 (2 months before Browning's predicted impact date) and Wave 2 (2 months after Browning's predicted impact date). Securing objects, the least popular adjustment, increased from 17% to 27%, whereas storing food and water increased from 51% to 70%, learning to shut off utilities increased from 66% to 87%, and insurance purchases increased from 56% to 71%.

In a well-controlled field experiment, Mulilis and Lippa (1990) provided respondents with specially prepared earthquake awareness brochures that systematically varied information about an earthquake's probability of occurrence, its severity, the efficacy of a recommended seismic adjustment, and the receiver's self-efficacy (i.e., capability) to implement the adjustment. The researchers found that the brochures did induce immediate changes in the receivers' perceptions of probability, severity, outcome efficacy, and self-efficacy but that these impacts were not sustained over the 5 to 9 weeks between the administration of an immediate posttest and a delayed posttest, and there were only suggestive rather than conclusive improvements in the level of seismic adjustment.

Some provocative data about the relative importance of social influences in comparison to other decision variables can be found in data from Palm et al. (1990) indicating that respondents rated social influences (e.g., informal sources, insurance salesperson, real estate agent, mortgage company, news media coverage) as less influential in affecting insurance purchase decisions than perceived characteristics of the hazard impact (extent of damage, cost of damage, and impact on household wealth) and of adjustments (availability of state or federal loans and cost of insurance). People's beliefs about the factors influencing their decisions are accurate under some circumstances but not others (see Ericsson & Simon, 1984; Nisbett & Ross, 1980). Thus, further study is needed to better understand the relative influence of different types of information.

Information seeking. Three studies have found evidence that information seeking is associated with seismic adjustment. Turner et al. (1986) found that adjustment adoption was related to discussion of earthquake topics and attendance at earthquake-related meetings. Moreover, Mileti and Fitzpatrick (1992) found that in all three communities they studied, post-prediction seismic adjustment had consistently high correlations with information seeking. This finding was confirmed by Mileti and Darlington's (1997) study of the response to the hazard awareness brochure in the San Francisco Bay area, which found that information seeking was the single best predictor of seismic adjustment.

Adoption of past adjustments. The correlation of past adjustments with seismic adjustment is inconsistent and may be contingent on contextual conditions. Mileti and O'Brien (1992) found that adjustment adoption for aftershocks from the Loma Prieta earthquake was predicted by long-term adjustments prior to, and emergency actions immediately after, the main shock. However, Mileti and Fitzpatrick's (1992) study of the response to the Parkfield prediction found nonsignificant correlations between past and current adoption of seismic adjustments, whereas Mileti and Darlington's (1997) study of the response to the hazard awareness brochure in the San Francisco Bay area found the correlation was significantly positive but small.

Behavioral intentions. Only one study has addressed the relationship of intended seismic adjustments to later adjustment adoption. Farley et al. (1993) reported that respondents' actual schedule changes in response to the Browning earthquake prediction were predicted by their planned schedule changes. In turn, respondents' planned schedule changes were predicted by planned changes by friends, employers, and children's schools. However, behavioral intentions overestimated actual behavior; far fewer households left town (1%) or changed their schedules (17%) than intended to do so (8% and 31%, respectively).

Personality characteristics. The studies reporting findings regarding personality characteristics are consistent. Turner et al. (1986) found that adjustment adoption was inversely related to fatalism about earthquake impacts. This finding was partially supported by Farley et al. (1993), who reported that adjustment adoption was predicted by lower fatalism in a survey conducted before the Browning earthquake prediction date but not in a survey conducted immediately after that prediction date. Although fatalism about earthquake impacts has been construed as a personality characteristic that reflects wide-ranging beliefs about the world in general, this construct also can be interpreted as measuring respondents' lack of awareness of any seismic adjustments at all (cf. Jackson & Mukerjee, 1974; Kunreuther et al., 1978; Sullivan et al., 1977), of any effective adjustments, or of any effective adjustments that meet their resource constraints.

Perceived protection responsibility. Jackson's (1977, 1981) research raised the possibility that low levels of seismic adjustment can be attributed to respondents' beliefs about who is responsible for coping with earthquakes; households (10%) were mentioned no more frequently than scientists (11%) or emergency services departments (11%). Responsibility was ascribed most frequently to local (23%), state (19%), and federal government (54%). More than a decade later, Garcia (1989) found that 98% of her respondents felt earthquake preparedness was an individual responsibility, but 68% also believed that local government should have emergency supplies for residents. A causal effect of perceived responsibility on seismic adjustment is suggested by the much higher levels of seismic adjustment adoption reported by Garcia (1989) than by Jackson (1977, 1981). This possibility is further supported by Mulilis and Duval (1995), who found that perceived personal protection responsibility had a significant effect on the adoption of seismic adjustments.

THEORETICAL IMPLICATIONS

The findings of the studies in Table 1 can be interpreted within the framework of the Protective Action Decision Model (PADM) (Lindell & Perry, 1992). PADM is a direct extension of earlier theories of emergent norms (Turner & Killian, 1972), response to environmental hazard vulnerability (Burton et al., 1978; Slovic, Kunreuther, & White, 1974), and emergency warning response (e.g., Janis & Mann, 1978; Perry, Lindell, & Greene, 1981) but has been revised in accordance with more recent findings about environmental risk perception (Lindell, 1994). According to PADM, awareness of a threat is initiated by environmental cues (sights or sounds), observations of others, or messages from informal, news media, or official sources that are perceived primarily in terms of expertise and trustworthiness. Threat perception motivates a search for an appropriate response to protect persons and property without unnecessarily disrupting normal activities. Clarification of the threat's significance and selection of an appropriate response is accomplished by searching memory for relevant knowledge; by observing friends, relatives, neighbors, and coworkers; and by seeking information from these informal, news media, or official sources.

Consistent with the TRA (Fishbein & Ajzen, 1975), PADM hypothesizes that protective action intention is a function of one's attitude toward that action and normative influences to engage in the action. PADM theorizes that evaluation of alternative actions (TRA's attitude toward a behavior) is motivated by perception of a hazard (TRA's attitude toward an object) as threatening to oneself. Thus, because beliefs about a protective action are more proximal to the adjustment adoption decision than are beliefs about a hazard event, the former are expected to be more highly correlated with adjustment adoption decisions than are the latter.

Perceived characteristics of a hazard and protective actions are equivalent to TRA's salient beliefs, but TRA does not specify what are respondents' salient beliefs for a particular attitude domain. PADM identifies risk area residents' salient beliefs about an environmental hazard in terms of the severity, certainty, immediacy, and duration of personal consequences such as personal injury, property damage, and disruption to one's work and social life. It also identifies risk area residents' salient beliefs about protective actions as efficacy for protecting persons and property, and requirements for time, skill, money, and effort. Beliefs about a hazard, adjustment attributes, and the adjustment context (e.g., variables that either facilitate or constrain respondents' willingness and ability to adopt various adjustments) vary as a function of hazard experience, social context (e.g., involvement with family, kin, and community), demographic characteristics (e.g., gender and age) and household resources (e.g., education and income).

Although PADM was developed to account for risk area populations' response to evacuation warnings, it has been extended to long-term volcano adjustment (Perry & Lindell, 1990). Moreover, it is consistent with broader literatures on behavioral decision making (Feldman & Lindell, 1990), health behavior (Weinstein, 1993), and attitude-behavior relations (Eagly & Chaiken, 1993). PADM also is compatible with Mulilis and Duval's (1995) PrE theory, a model that originally was adapted from protection motivation theory (Rogers, 1975) to explain seismic adjustment. Despite their independent origins, PADM and PrE identify many of the same variables as relevant to the adoption of seismic adjustments. Both models distinguish two categories of important salient beliefs. In PrE, environmental demands are defined in terms of the probability, magnitude, and immediacy of an event, and personal resources are defined by self-efficacy and response efficacy. PADM defines perceived personal consequences in terms of the same attributes as PrE's environmental demands but distinguishes these from perceived characteristics of a hazard agent and perceived characteristics of hazard impact (Lindell, 1994). PrE does not differentiate perceived personal consequences from other hazard characteristics.

A seismic adjustment's perceived efficacy in PADM is equivalent to its response efficacy in PrE, whereas PADM's time, skill, money, and effort requirements refer to the same construct as PrE's self-efficacy but are more specific components of it. Finally, tests of PrE assume that protection motivation arises from the interaction of environmental demands (PADM's perceived risk) and personal resources (PADM's perceived adjustment attributes), so the separate effects of these two constructs have not been reported. For example, Mulilis and Lippa (1990) found evidence of increased earthquake preparedness for a treatment group in which perceptions of environmental demands and personal resources had been increased by special hazard awareness brochures. Similarly, Mulilis and Duval (1995) found that adoption of seismic adjustments was greater among those who were persuaded to perceive their resources as significantly greater than event demands, whereas adoption was lower among those led to believe their resources were equal to or significantly less than event demands. Unfortunately, neither study reported the correlations of the manipulation checks with seismic adjustment, so it is not possible to assess the relative importance of environmental demands and personal resources.

Empirical support for the theoretical models. Studies of seismic adjustment have addressed most of the important variables in PADM and have confirmed that these variables affect long-term seismic adjustment as well as short-term warning response. Specifically, the studies in Table 1 have confirmed that observations of others' behavior and receipt of information from social sources play a major role in seismic adjustment. These studies also have documented the importance of risk area residents' search for information to confirm any warnings that they have received. Consistent with PADM and PrE, many studies have found that perceptions of specific hazard characteristics are correlated with seismic adjustment. The most frequently measured hazard characteristics are the certainty and severity of personal consequences, especially the likelihood of death, injury, and property damage. Some investigators have assessed perceptions of the likelihood of an earthquake rather than the likelihood of the personal consequences of that event and found the latter to be smaller than the former (Mileti & O'Brien, 1992). Consequently, perceived event likelihood has yielded significant correlations with adjustment adoption in some studies (Mileti & O'Brien, 1992; Mulilis & Duval, 1995) but not others (Mulilis & Lippa, 1990).

Also consistent with the PADM and PrE models, some studies have found that perceptions of seismic adjustment attributes are correlated with seismic adjustment, whereas other studies have explained differences in the popularity of different adjustments in terms of the adjustment attributes proposed by PADM. Nonetheless, the post hoc explanations are clearly speculative and the empirical findings are suggestive rather than definitive.

Further consistency with PADM can be found in the fact that proximity to the hazard source and past hazard experience have been found to predict seismic adjustment, although the effects are somewhat inconsistent. Moreover, PADM does list some demographic characteristics and community context variables that are relevant to seismic adjustment (ethnicity, age, socioeconomic status, and community integration), but it provides only a limited discussion of the mediating mechanisms by which these variables' effects are achieved because they appear to affect multiple stages of the protective action decision-making process (Lindell & Perry, 1992). Studies of seismic adjustment have reported significant correlations for respondents' ethnicity, age, socioeconomic status (education, income, and profession), and community integration. Consistent with PADM's prediction of an effect for internal-external fate control, seismic adjustment studies have found evidence of an effect for the related construct of fatalism.

AN UPDATED THEORETICAL MODEL

There are some discrepancies between PADM and the findings of research on seismic adjustment that suggest a need for modifying theory. The model depicted in Figure 1 augments Lindell and Perry's (1992) PADM model by showing interrelationships among the hazard, the household, the social context, and seismic adjustments. Households and their social context are linked to a hazard by their vulnerability to the hazard. Vulnerability is defined in terms of impacts on personal safety and health, property (tangible and financial), and routine activities (e.g., working, shopping, and recreation) and arises principally from risk area residents' proximity to seismic faults and the characteristics of the built environment that they occupy. Households and their social context are linked to seismic adjustments by the resources that they allocate to those adjustments. Resources include equipment and materials, money, knowledge and skill, and time and effort. Households are linked to their social context by mutual influence. Finally, adjustments are linked to the hazard by the adjustment's efficacy in reducing hazard vulnerability. Past hazard experience, which is not directly represented in this figure, affects households by providing them with important information about hazard vulnerability, adjustment efficacy, and adjustments' resource requirements. Stakeholders in the social context affect households by providing opportunities to vicariously experience hazard impacts and observe the adoption of seismic adjustments. Other stakeholders also affect households by providing them with material resources needed for adopting seismic adjustments, responding to their information seeking, and deliberately attempting to persuade them to adopt seismic adjustments. Such persuasion can occur through informational influence or normative influence. Fishbein and Ajzen (1975) have suggested that the latter affects behavior through people's beliefs about the action preferences of significant others and their motivation to comply with those others' preferences.

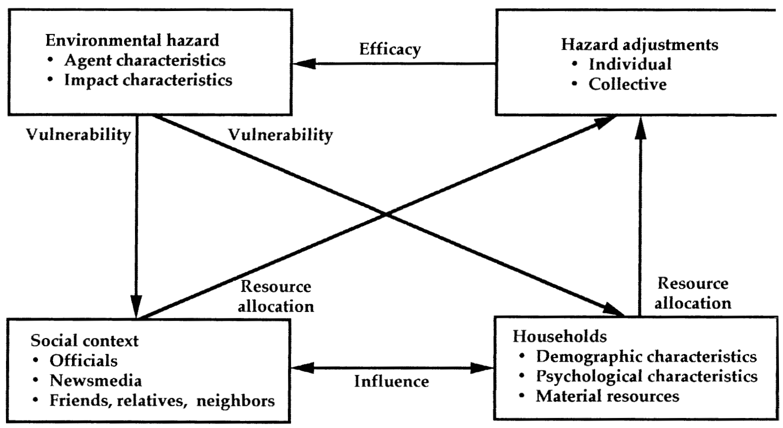

Figure 1: Interrelationships Among Environmental Hazards, Households, Social Context, and Hazard Adjustments

RECOMMENDATIONS FOR FUTURE RESEARCH

In addition to theory revision, there also is a need for further research in six major areas: seismic adjustments, perceived hazard characteristics, perceived adjustment characteristics, household characteristics, past experience, and social influences.

Seismic adjustments. A pressing need for future research is to adopt a consistent typology of pre-impact seismic adjustments, to develop standardized scales for measuring these adjustments, and to assess the psychometric adequacy of these scales (cf. Mulilis & Lippa, 1990). Some studies have addressed only a single adjustment, earthquake insurance, whereas others have examined lists of preparedness actions commonly recommended by authorities. Future studies should address the adoption of adjustments from all three categories—hazard mitigation, emergency preparedness, and insurance purchase. Following Russell et al. (1995), separate subscales for these three categories of seismic adjustments should be created to determine if they have different antecedents. Future studies also should systematically develop and test scales measuring the information-seeking activities that have been reported to be highly correlated with adjustment (Mileti & Darlington, 1997; Mileti & Fitzpatrick, 1993). These information-seeking scales should distinguish between search for information about the hazard and about adjustments.

Weinstein and Nicolich's (1993) analysis indicates that it is important for future research to distinguish between past adjustments and intentions to adopt future adjustments. This is related to a distinction between activities and states. Activities such as information seeking or insurance purchase are intended to attain a corresponding state such as hazard knowledge or possession of insurance coverage. It is the state that usually is most directly relevant to seismic adjustment, not the activity directed toward attaining that state, because the activity may only be temporary while the state persists. The importance of this distinction is underscored by Mileti and Darlington's (1997) finding that education was negatively correlated with seismic adjustment following a hazard awareness campaign because the most highly educated risk area residents already had adopted many seismic adjustments.

Another important task for future research is to assess the perceived interdependencies among seismic adjustments. Adjustments are likely to be positively correlated if the information and other resources acquired in the process of adopting one adjustment make it easier to adopt other adjustments. This implies that an adjustment perceived as having more efficacy and lower resource requirements might serve as a gateway to the adoption of adjustments that are perceived to be lower in efficacy and more resource demanding. This sequential ordering is supported by findings that mitigation and preparedness adjustments are predicted by previous hazard-relevant responses, especially information seeking (Mileti & O'Brien, 1992; Turner et al., 1986).

Perceived hazard characteristics. Previous research generally has reported statistically significant relations between perceived hazard characteristics and seismic adjustment, but the size of the correlation coefficients is modest. One potential explanation for the small correlations is that researchers have failed to accurately capture risk area residents' cognitive representations of the hazard. Most research on seismic adjustment has measured perceived characteristics of earthquakes in terms of respondents' judgments of the probability and severity of personal consequences, but other beliefs also are relevant. Mileti and Fitzpatrick (1993) assessed respondents' perceptions of the probability of a major earthquake, property damage, injury, and death and, moreover, assessed perceptions of these consequences over two different time periods. As noted earlier, PADM categorizes environmental risk perceptions into three categories: hazard agent characteristics, impact characteristics, and social consequences (Lindell, 1994). Hazard agent characteristics include the location, magnitude, timing, and probability of an event, whereas hazard impact characteristics include speed of onset, presence of environmental cues, and scope and duration of impact. Social consequences can be characterized in terms of their targets, types, and descriptive attributes. Targets include self and family; friends, relatives, neighbors, and coworkers; and other community members. The types of consequences include personal safety (death and injury), property damage, income loss, and community disruption. Descriptive attributes of past consequences include severity, frequency, recency, and duration. These give rise to the corresponding expectations of future severity, certainty, immediacy, and duration.

None of the studies in Table 1 investigated the effects of impact duration and only one directly examined respondents' perceptions of the impact immediacy (Mulilis & Duval, 1995). Duration may not be important for some consequences where it is clearly implied (e.g., death), but beliefs about the duration of income loss or community disruption could vary significantly from one person to another and could affect the adoption of adjustments. Similarly, neglect of immediacy would not be a significant omission if all respondents equated immediacy with high probability and, conversely, remoteness in time with low probability. Although there is evidence that at least some respondents do make this error (Slovic et al., 1974), failure to measure immediacy may misrepresent the threat perceptions of respondents who do distinguish between these two threat characteristics. Immediacy was indirectly addressed by Mileti and Darlington (1995), who asked respondents to judge the likelihood of personal consequences from an earthquake in the next few years and also within the next 5 years. Consistent with the tenets of statistical theory and other research on perceptions of cumulative risk (see Doyle, 1997), more people agreed that they would be affected in their lifetime than within the next few years.

Researchers also should assess the linkages among people's beliefs about seismic hazard to identify the preconditions for risk personalization. Palm and Hodgson's (1992) work suggests assessing the locational, structural, and demographic components of perceived vulnerability. With respect to perceived locational vulnerability, studies should examine people's actual and perceived proximity to earthquake faults (Palm & Hodgson, 1992, noted the latter typically are inaccurate) and compare these with corresponding perceptions of the scope of impact of earthquakes generated by that fault. Palm and Hodgson (1992) provided data on an actual impact gradient that showed the proportion of damaged houses as a function of proximity to the earthquake fault. The corresponding idea of a perceived danger gradient—the decrease in danger as a function of increasing distance—previously has been addressed in studies of earthquake (Sullivan et al., 1977), volcano (Lindell, 1994), and technological (Lindell, 1994; Lindell & Barnes, 1986) hazards. Perceived structural vulnerability could be assessed by asking respondents to compare the vulnerability of the structures in which they live and work to the vulnerability of the average home, whereas perceived demographic vulnerability could be assessed by obtaining respondents' comparisons of their household members' vulnerability to that of the average household.

In attempting to assess perceived hazard characteristics by using standardized rating scales, researchers must recognize that survey respondents' answers can be unstable (and, in extreme cases, altogether worthless) when attitude objects are rated on dimensions that have no meaning to the respondents. Under such circumstances, nonattitudes (Converse, 1964; Schuman & Kalton, 1985) are elicited from those who have not thought about the topic before administration of the survey instrument. One procedure for avoiding nonattitudes is to assess the stability of respondents' perceptions over time. Lindell and Perry (1990) compared respondents' hazard perceptions at two points in time in terms of the difference in mean ratings (either statistically significant or not) and the correlation between ratings at the two points in time (either statistically significant or not). This procedure allowed the variables to be classified into four types. Stable perceptions showed nonsignificant differences in means and statistically significant correlations between Time 1 and Time 2. Reliably changed perceptions showed significant differences in means and statistically significant correlations between Time 1 and Time 2. Unreliable perceptions showed nonsignificant changes in means and nonsignificant correlations between Time 1 and Time 2. Inconsistently changed perceptions showed significant differences in means but nonsignificant correlations between the two points in time. The fact that some perceived risk characteristics fell into each of these four categories indicates that assessing the stability of risk perceptions requires more sophisticated measurement procedures than are commonly used in hazards research.

Another method of avoiding nonattitudes is to conduct additional studies that repeat Jackson's (1979, 1981; Jackson & Mukerjee, 1974) use of free response items to assess respondents' salient beliefs about seismic hazard. Further evidence of the value of free response data is found in Perry and Lindell's (1990) study of volcanic adjustments made by residents of the area around Mt. St. Helens. This study found that the number of social consequences of hazard impact mentioned by respondents (which Fishbein & Ajzen, 1975, would call the number of salient beliefs) was positively correlated with respondents' perceptions of the risk to personal safety and property. In addition, the number of salient beliefs was correlated with such outcomes as overall salience of volcano hazard (measured by frequency of thought about it), overall level of personal planning activity, and the actual number of volcanic adjustments. Significantly, the number of salient beliefs about the hazard was a better predictor of hazard adjustment than were the variables typically used to measure risk perception in most studies.

Finally, some investigators have measured respondents' hazard concern (e.g., Dooley et al., 1992) or their personalization of the threat (Mileti & Fitzpatrick, 1993). These variables can be interpreted as being equivalent to an overall perception of the threat in PADM or to total event demands in PrE. If risk area residents have only very diffuse conceptions of seismic threat, then a global construct may be a more accurate characterization of their beliefs than the specific dimensions assumed by PADM and PrE. Further research is needed to determine what proportions of the population have specific beliefs, global beliefs, and no beliefs at all about seismic hazard.

Perceived adjustment attributes. Further research also is needed to identify the attributes that risk area residents use to evaluate seismic adjustments. As Figure 1 indicates, the arcs linking hazard adjustments to the hazard and also to household resources imply that attributes of hazard adjustments can be categorized as hazard-related or resource-related. Hazard-related characteristics include efficacy for protecting persons and property and utility for other purposes. By contrast, resource-related characteristics are defined by demands on household resources such as money, knowledge, skill, time, effort, and interpersonal cooperation. Such characteristics are closely linked to household members' self-efficacy, which refers to a belief in the adequacy of one's knowledge and skills as well as access to any materials, equipment, and money that also are needed. This conception of resource-related adjustment characteristics is similar to PrE's proposition that adjustment adoption is a function of the overall level of resources in relation to environmental demands but differs in distinguishing between a hazard and an adjustment as two distinct parts of the environment.

Attributions of protection responsibility. Seismic adjustment studies have suggested that perceived protection responsibility might be an important omission from PADM, but the research base is quite limited. As noted earlier, it has been reported repeatedly that many risk area residents hold government responsible for reducing seismic vulnerability (Jackson, 1981; Mulilis & Duval, 1995; Turner et al., 1986). Future research should explore the role of different levels of government in relation to informal sources such as friends, relatives, neighbors, and coworkers.

Household characteristics. Future research should examine the role of community bondedness. The empirically significant correlations between community bondedness and seismic adjustment originally reported by Turner and his colleagues (1986) have been replicated by some (Dooley et al., 1992) but not others (e.g., Palm et al., 1990). These inconsistencies cannot be explained by sampling fluctuations because of these studies' large sample sizes. It is likely that the magnitude of the correlations between household characteristics and seismic adjustments depend on which household characteristics and seismic adjustments are being correlated. This explanation is quite plausible because the variables used to measure household characteristics and seismic adjustments have differed from one study to another. For example, Turner et al. (1986) correlated one set of household characteristics with a multi-item index of seismic adjustment, whereas Palm et al. (1990) correlated a somewhat different set of household characteristics with insurance purchases. Future investigations of seismic adjustment should consistently measure the same set of household characteristics and, to avoid reporting bias, present the entire matrix of correlations—even the nonsignificant coefficients.

Once household characteristics have been identified that consistently predict each type of seismic adjustment, it should be possible to identify the mediating mechanisms by which they exert their effects. According to Fishbein and Ajzen (1975), noncognitive variables such as household characteristics affect behavior through attitudes toward the behavior and subjective norms. Thus, correlations between household characteristics and adjustments should be completely mediated by hazard perceptions, adjustment perceptions, and subjective norms. However, some investigators (Bentler & Speckart, 1979) have reported data inconsistent with this tenet of TRA. Lack of complete mediation by attitudes and subjective norms also is consistent with Petty and Cacioppo's (1986) distinction between central and peripheral routes to persuasion and Chaiken's (1987) distinction between systematic and heuristic processes. Both theories assert that noncognitive factors can affect attitudes and behavior without affecting salient beliefs or subjective norms.

Correlations of demographic variables with adjustment adoption may be valuable in allowing hazard managers to target population segments that are most disposed to adopt seismic adjustments. For example, the presence of school-age children in the home might signal a need to focus on schools as a channel for disseminating hazard information, whereas correlations of income with overall adjustment might suggest an emphasis on the least expensive adjustments, at least until risk area residents become more committed to the seismic adjustment process.

Past experience. Past earthquake experience has been found by some, but not all, investigators to predict seismic adjustment. One possible explanation for the lack of consistency is that this construct has been measured in a variety of different ways ranging from whether respondents have felt any earthquake tremors to the amount of damage suffered in previous earthquakes. These variations in the measurement of earthquake experience, which are similar to those found in research on hurricane adjustments (Baker, 1991), suggest that the construct, hazard experience, needs to be more carefully conceptualized and more consistently measured. One important contribution that could be made in future studies would be to assess hazard experience in terms of dimensions that correspond to the categories of risk perception assessed by Lindell (1994). Specifically, this might include the number of earthquakes felt, as well as their social consequences, characterized in terms of their targets (oneself; one's immediate family; and one's friends, relatives and neighbors), and types of impact (injury, property damage, utility outage, and job disruption). Assessing hazard experience in this comprehensive manner could provide a basis for determining what forms of experience have the greatest impact on seismic adjustment. Moreover, future research should assess the connections between the characteristics of seismic events that people actually have experienced in the past and their corresponding beliefs about possible future events. Jackson's (1981) research suggests that the relationships may be complex because the effect of past experience on expectations of future damage appear to depend on respondents' beliefs about the probabilistic nature of the hazard.

Of course, showing a link between past hazard experience and adoption of seismic adjustments does not help hazard managers directly because it is not possible to increase the level of adjustment by providing direct hazard experience and would not be desirable even if it were possible. An important task for future researchers will be to identify what it is about direct experience that increases seismic adjustment and to develop methods of providing these critical elements vicariously rather than directly.

Social influences. Researchers long have recognized that hazard adjustment takes place in a social context. Accordingly, social influence has been examined in many studies of seismic adjustment, but most of these have focused on persuasive influences. Consistent with the dominant approach to persuasion, these studies have addressed source, message, channel, receiver, and effect variables (O'Keefe, 1990). For example, Turner and his colleagues (1986) examined the differential effects of prophetic and scientific sources on hazard perception, a perspective that is somewhat similar to disaster studies studying the effects of informal, news media, and official sources on warning response. Future research should complement investigation of influence sources with an examination of the basis of influence. Raven (1993;

French & Raven, 1959) has concluded that sources use six bases of influence—legitimate, referent, expert, information, reward, and coercive. A slightly different typology arises from the literature on persuasive communications, which indicates that sources are perceived in terms of their credibility (e.g., expertise and trustworthiness), attractiveness, and power (Eagly & Chaiken, 1993). Further examination of the characteristics of information sources and their bases of influence could substantially advance our understanding of this aspect of the seismic adjustment process.

Message characteristics—information quality (specificity, consistency, and source certainty) and information reinforcement (number of warnings)—have a significant impact on adoption of seismic adjustments. However, only a few studies have examined this component of the seismic adjustment process (Mileti & Fitzpatrick, 1992; Mileti & O'Brien, 1992). Future research should examine whether there are other message characteristics that also affect adjustment.

The differential impact of communication channels has been examined, with Turner et al. (1986) finding that television had a greater impact than other media. However, other research found residents of a rural area vulnerable to volcano hazard had complex patterns of communications channel use (Perry & Lindell, 1990) and that channel use varies by community and ethnicity (Lindell & Perry, 1992). Moreover, risk area residents use channels for different purposes; radio and television are useful for immediate updates, meetings are useful for clarifying questions, and newspapers and brochures are useful for retaining information that might be needed later. The ways in which residents of seismic risk areas use the mass media need similar scrutiny.

Finally, Turner et al. (1986) conducted an innovative analysis of message effects by distinguishing among those who had only heard about the Palmdale Bulge, those who had heard and understood the significance of this event, and those who heard, understood and perceived the event to be personally relevant. The similarity between Turner and his colleagues' information-processing stages and the first three of McGuire's (1969) five stages—attention, comprehension, yielding, retention, and action—suggest that further investigation of the overlaps between natural hazard risk communication and experimental social psychological studies of persuasion would provide a better understanding of the ways in which the process of hazard adjustment adoption is affected by stages of information processing. A preliminary step in this direction has been taken by studies examining respondents' recall of hazard message content (Mileti & Darlington, 1997; Mileti & Fitzpatrick, 1993), but more work needs to be done.

SUMMARY

Past research on household seismic adjustment underscores a need for better theories, better testing of existing theories, and better data analytic and data reporting procedures for future tests of those theories. This review proposes preliminary steps toward all three aims. Some models of hazard adjustment neglect the social context, whereas others provide poor accounts of people's cognitive representations of earthquake hazard and the ways in which these representations are affected by such antecedents as previous hazard experience and social influence. Improving existing theories requires hazard researchers to recognize the relevance of the broader literature on attitudes (e.g., Eagly & Chaiken, 1993), whereas better testing of existing theories necessitates the assessment of a broader range of constructs within each study.

Researchers should use sample frames with $N > 200$ and preferably $N > 400$ that are drawn from diverse locations. Mail-out questionnaire administration procedures should follow the procedures of the Total Design Method (Dillman, 1983) and the adequacy of the sample should be described in terms of the criteria listed in Sudman's (1983) sample credibility scale—geographic spread, discussion of limitations, use of special populations, sample size, sample execution, and use of resources. Following Bourque et al. (1997), telephone response rates should be calculated by dividing the number of completed interviews by the number of usable numbers (a lower bound estimate), and also by dividing the number of completed interviews by the number of usable phone numbers minus the number of no-contact phone numbers (an upper bound estimate). Equivalently, response rates for mail-out questionnaires can be calculated by dividing the number of returned questionnaires by the total number of mailed questionnaires minus the number of noncontacts.

Researchers can improve their data analytic and data reporting procedures by following Mileti and Darlington (1997) in providing all of the information needed for meta-analytic assessments (e.g., Rosenthal, 1991). They should form multi-item scales wherever possible and report their means, standard deviations, reliabilities, and intercorrelations. They also should report the item popularities of the individual adjustments used in any overall scale. Moreover, the cross-sectional nature of these correlations makes it difficult to determine if hazard perceptions cause adjustments or, conversely, if adjustments cause hazard perceptions. The latter possibility is consistent with a significant body of literature on attitude change (Eagly & Chaiken, 1993) and has been addressed empirically by De Man and Simpson-Housley (1987) and theoretically by Weinstein and Nicolich (1993). Cross-sectional studies of factors associated with the adoption of seismic adjustments would be well advised to supplement reports of current adjustment adoption with the collection of either retrospective reports of past adoption or behavioral intentions for future adoption. Such quasi-longitudinal designs are inferior to true longitudinal designs that collect data on adjustment adoption at two different points in time but are far superior to pure cross-sectional designs.

Finally, general conclusions from previous research on seismic adjustment are somewhat problematic because 20 of the 23 studies have been conducted in California. The seismic vulnerability of other states throughout the country warrants efforts to determine if existing research results are specific to California or can be generalized to other locations where pre-impact seismic adjustments should be adopted.

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