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FACTORS RELATED TO FLOOD WARNING RESPONSE

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Abstract. A synthesis is presented of the social psychological process that explains how members of the public receive, process, and eventually come to take protective actions in response to the receipt of warnings of extreme floods. The case is made that effective public warnings must provide for public interaction and foster the search for information in addition to received warnings. In fact, the communication of climatological, geological and technological hazards, risk, and disaster information and warnings to the public is an almost continual process when viewed globally. For example, it has been estimated that an evacuation a day occurs on average in the United States alone. Warnings are issued for varied risks, for example, hurricanes, floods, volcanic eruptions, earthquakes, and transported or stored hazardous materials. Hazards such as these vary in character, but they are similar in that they can result in low-probability/high-consequence disaster events, and because the basic social psychological process that directs public response is similar across hazards. It is the purpose of this paper to synthesize research and knowledge on the process that underlies public response to warnings of disasters. Several specific recommendations for future research are presented.

1. PUBLIC WARNING RESPONSE IS A SOCIAL PROCESS

Public reaction to warnings of impending disaster is not well characterized by a stimulus-response model. For example, a warning need only be heard to be followed by taking a protective action. Instead, people who receive warnings first typically go through a social psychological process to form personal definitions about the risk they face and ideas about what to do before they take a protective action. The process is readily divided into several phases: (1) hearing a warning, (2) forming a personal understanding of what was meant by the warning, (3) developing a level of belief in the risk information conveyed in the warning, (4) personalizing the risk or perceiving to be someone else's problem, and (5) deciding what if anything to do and responding in ways thought to be appropriate for the risk personally faced. Public warning systems that take this process into account can be very effective in helping at-risk publics find safety before disasters strike. Warning systems that are not designed to take the social psychology of public warning response into account are much less likely to foster pre-disaster public protective actions.

1.1 HEAR

The first stage in the social psychological process of public response to hazard warnings is hearing that there is an emergency, typically through a public warning like a siren or a worded warning message (Mileti and Sorensen 1987). It cannot be assumed, however, everyone in a public will hear every public emergency warning. Even when it is physically possible for people to hear a warning, various factors may inhibit a message from actually being heard. People may fail to listen because of habituation (for example, they never really listen to radio or television) or selective perception (for example, they hear only what they want to hear because a predisposed bias to maintain a routine in their lives). The failure to hear a warning generally precludes or at least delays self-protective action (cf., Anderson 1969; Turner et al. 1981; Lardry and Rogers 1982; Perry and Lindell 1986; Bellamy 1987; Tierney 1987).

1.2 UNDERSTAND

Second, once heard, the information in a warning must be understood. This does not mean understanding what is heard, but rather personally attaching meaning to the message. Meaning or understanding varies among people, and these varied understandings may or may not conform to the meaning intended by those who issued the warning (cf., Haas, Cochrane, and Eddy 1977; Foster 1980; Perry, Lindell, and Greene 1981; Lehto and Miller 1986). For example, one person may understand a flood warning as referring to a high wall of inundating water, whereas another may only visualize ankle-high runoff. Volcanic ashfall may be construed as a suffocating blanketing coverage or as a light dusting of powder; and a 50 percent probability of occurrence may be interpreted as certainty by some or unlikely by others. These examples illustrate that different people can understand warning messages differently.

Additionally, understanding a warning is connected to people's frames of knowledge and reference. It may be difficult for people to understand a hazard warning when they do not understand much about the hazard. In this sense, understanding also defines and bounds perception of risk and what to do about it. Emergency warning information must thus be able to provide the public with accurate and common understandings of risk and hazards. The different understandings that might emerge among people if an emergency occurred can be avoided with proper planning. For example, a public that is educated about a hazard, long before warnings are ever issued, will more readily understand warnings when they are issued in the future.

1.3 BELIEVE

Protective public action is also encouraged if people believe that the warning is real and that the contents of the message are accurate. But belief in heard warning messages typically varies among the public (cf. Clifford 1956; Wallace 1956; Demerath 1957; Williams 1957; Fritz 1961; Moore, Bates, Layman and Parenton 1963; Drabek 1969; Mileti 1975; Mileti, Drabek, and Haas 1975; Quarantelli 1980; Yamamoto and Quarantelli 1982).

1.4 PERSONALIZE

People also consider the implications of warnings for themselves and their groups, e.g., their family. If people do not think that emergency information was meant for them (the "it-can't-happen-to-me" syndrome), they likely will ignore it. If people think they are the intended targets of emergency information (the "it-must-be-me" syndrome), they may act accordingly. Personalization

can lead to both under-response and over-response in emergencies (Perry et al. 1983; Nigg, 1987).

1.5 RESPOND

Finally, when a person has heard the emergency information, formed an understanding of what is being said, defined a level of belief in what is being said, and determined a level of risk personalization, then behavior follows based on the personal perceptions formed (cf., McLuckie 1970; Mileti et al. 1975; Baker 1979; Flynn and Chalmers 1980; Quarantelli 1980; Nigg 1987; Perry, 1981). A person typically goes through these phases each time new warning information is received.

1.6 CONFIRMATION

People do not passively await the arrival of more information in a warning circumstance. Instead, most people actively seek out additional information. When warning information is received, most people try to verify what they heard by seeking out information in another warning message or from another warning source or person. Seeking new information to confirm prior warnings or receiving new information that confirms prior information is typically referred to as the warning confirmation process (Danzig, Thayer, and Galater 1958; Drabek 1969; Drabek and Stephenson 1971; Mileti et al. 1975; Quarantelli 1984).

Confirmation is a main reason that telephone lines and other ways that people communicate with one another become busy after a public emergency warning is issued; people call friends and relatives to get their interpretation of the event and to find out what they are going to do. Confirmation occurs because people are information-hungry following receipt of warnings. Rarely are people overwhelmed by information in a warning context. Instead, there is an information void caused by uncertainty, particularly when rare or unfamiliar events are about to occur. This void typically creates a public demand for more information than is being disseminated in the warning message. Confirmation, then, plays an important role in the warning process and is a part of each stage in the social process; it facilitates understanding, belief, personalization, and decision making (Mileti and Sorensen 1990).

1.6 SUMMARY

To reiterate, the warning-response process begins when the warning is heard. Although hearing a warning precedes response, hearing by itself is often insufficient to make people take action. The next stage is understanding the warning. Then people must come to believe that the warning is true and accurate. Next, people must personalize the message to make it relevant to themselves. Finally, they must decide to take action and overcome constraints to taking that action. People usually follow their decision about responding unless constraints prevent them from doing so (for example, lacking an automobile in which to evacuate). These responder and situational characteristics vary widely among members of a public in a warning circumstance, as well as between different events. As discussed in the next section, what happens at each step in the process is also the result of interaction between those who send emergency information (the "senders") and those in the public who receive it (the "receivers").

The long-established principle that people behave in response to hazard warnings in ways consistent with their situational perceptions of risk has been researched in a variety of natural and technological emergencies and cultures. Early works were followed by dozens of investigations on

how situational risk perception influences behavior in an emergency. There are many studies of good quality across a variety of emergency types to provide, when viewed collectively, both scholars and planners with sound knowledge about how and why the public comes to respond to hazard warnings. Determinants of risk perception and behavior can readily be grouped in terms of warning system or "sender" and "receiver" or situational characteristics in the hazard warning communication process. The single most important factor that influences public response to warnings is confirming risk information through interacting with others and searching for additional confirmatory information.

2. WARNING FACTORS THAT INFLUENCE PUBLIC RESPONSE

2.1 WARNING SOURCE

First is the source of the warning information. The individual or agency from which the emergency public information or warnings emanate must seem credible and reliable to the people receiving the warnings. Warnings are most believable if they come from a mixed set of persons, because people have different views about who is credible and who is not. Warning messages that contain endorsement by a mix of scientists, organizations, and officials serve to alleviate the possibility that any one source could be deemed non-credible (cf. Drabek 1969; Drabek and Stephenson 1971; Mileti et al. 1981). For example, a warning message from a mixed set of sources could say "The mayor and the head of civil defense have just conferred with scientists from our local university and the National Volcano Observatory as well as with the head of our local Red Cross chapter, and we now wish to warn you that...."

2.2 WARNING MESSAGE CONSISTENCY

Second, message consistency is also a determinant of understanding, belief, and personalization. Early documentation of this relationship was provided in a study of the Rio Grande flood (Clifford 1956) which found that inconsistent information caused confusion; people were less likely to understand or believe that the flood was going to occur. Fritz (1961) reached the same finding in a study of warning response across a range of disaster types. The message must also be consistent in the way it conveys information about the level of risk.

A warning message is best if it contains consistency in the information it gives and the tone in which it is given (cf. Drabek 1969; Foster 1980; Perry and Greene 1982; Sorensen 1982 and 1985; Quarantelli 1984; Rogers 1985). Inconsistency in the tone or information in a message creates confusion and uncertainty among recipients. It is not consistent to tell a public to evacuate but that their children will be kept in neighborhood schools. Nor is it consistent for a message to imply that something bad is about to happen but there is no cause for concern.

Unfortunately, in most emergencies there are numerous inconsistencies across different warnings as more is learned about the impending event and updates are issued. For example, inconsistencies can appear as new information reveals that the hazard has decreased or increased, the number of people at risk has become larger or smaller, and so on. Updating of the situation with explanations for changed conditions can reduce inconsistency.

2.3 MESSAGE ACCURACY

A third dimension is the accuracy of what is said in an emergency message. A warning message must contain accurate, timely, and complete data. Accuracy is the extent to which the contents of a message about risk, location, and what to do is or is not fully factual. If people learn or suspect that they are not receiving the "whole truth," they are likely to ignore instructions about how to respond, and instead respond in ways consistent with their suspicions. Errors in past warnings have been found to cause people not to believe subsequent warnings (Mileti et al. 1975). Simply being fully open and honest with the public about a hazard enhances accuracy. In addition, accuracy is important in parts of the warning that may be viewed by officials as being trivial. For example, calling Broad Street "Board" Street by mistake may send a signal to the public that other essential information is also incorrect even though message recipients can correct the error on the basis of personal knowledge.

2.4 WARNING CLARITY

Fourth is the clarity of the emergency information. A warning message must be worded clearly and in simple language that can be understood so that people know what is happening and what they should do about it (Quarantelli 1984, 104). Lack of clarity in a message can lead to people misunderstanding the message (cf., Williams 1957; McLuckie 1970; Drabek and Stephenson 1971). For example, in a nuclear power plant emergency, instead of saying "A possible transient excursion of the reactor resulting in a sudden relocation of the core materials outside the containment vessel" a good warning might simply say that "Some radiation may escape from a hole in the nuclear reactor."

2.5 CERTAINTY OF THE MESSAGE

Fifth, a message must convey a high level of *certainty* about the events taking place and what people should do. Even if there is a low probability or an ambiguous situation, the message about it should be stated with certainty. A message characterized by certainty might say, for example, "There is no way for us to know with total certainty if the volcano will actually erupt by 3:00 p.m., but we have decided to recommend that everyone be fully evacuated before then, and act as if the eruption threat is a real one." Certainty determines the level of belief in a warning and affects decision making (cf. Turner et al. 1979; Perry, Lindell, and Greene 1982). In a study of response to earthquake prediction, for example, Mileti et al. (1981) found that warnings become more believable as the probabilities attached to them become greater. Certainty in warning messages extends beyond message content to include the tone with which it is delivered to the public. The warning should be spoken by the person delivering it as if he or she believes or is certain about what is being said. If warnings are certain, decisions to respond are more likely.

2.6 SUFFICIENT INFORMATION

Sixth, sufficient information should be given in a message so that the public has an idea of exactly what is happening. Not knowing, or feeling that one has insufficient information creates confusion, uncertainty, and anxiety. Whereas too much detail in the message may overwhelm people, the message must contain enough information so that the public's first response is not to fill the information void with uninformed misperceptions or fears. The amount of information

provided affects understanding, personalization, and decision making. A study of family response to hurricane and flood warnings by Leik, Carter, and Clark (1981), for example, found that general and vague warnings caused people not to take protective actions. In a study of response to the Mt. St. Helen's volcanic eruption it was found that more detailed information led to higher levels of perceived risk, and, therefore, increased the odds that members of the public took protective action (Perry and Greene 1983).

A warning message, then, must provide the public with sufficient information about the impending hazard by describing the event that may occur and how it poses a danger to people. It is insufficient, for example, for a warning to simply state that lahars will accompany an eruption. The warning must also describe the height and speed of impact that will ensue, and the size and location of the areas that could be effected. A warning could describe "a wall of water 20 feet high moving at 40 miles per hour" for a flash flood, "an explosion hotter than the inside of the sun covering half of the county" for a nuclear explosion, or "a seismic shake severe enough to bring down half the unreinforced brick buildings in the city" for an earthquake. If a hazard is well described, people are better able to understand the logic of the protective actions that are being recommended and are provided with a rationale for subsequent behavior. Hazards should be described with sufficient enough detail so that all members of the public understand the character of the disaster agent from which they are to protect themselves. Informing the public about the physical characteristics of the hazard will reduce the number of people in an endangered public who misperceive the hazard and then make poor response decisions because of those misperceptions.

2.7 GUIDANCE

Seventh, and perhaps most important, a warning message must contain a clear statement of guidance and specifics about what people should do about the event being described, and how much time they have in which to act. It cannot be assumed that members of the public will know what constitutes an appropriate protective action; the protective action must be described. Public understanding of communicated emergency risk information is enhanced if it is specific regarding the risk, the hazard, what the public should do, and how much time is available before impact (cf. Drabek and Bongs 1968; Mileti and Beck 1975; Flynn 1979; Dynes, Purcell, Wenger, Stern, Stallings, and Johnson 1979; Carter 1980; Perry and Greene 1982; Perry, Greene, and Mushkatel 1983; Quarantelli 1984; Nigg 1987). A study of the Big Thompson Canyon flood found, for example, that people who received warnings during the flood were not necessarily advised on what to do (Gruntfest 1977). As a consequence, many who were warned incorrectly attempted to drive out of the canyon and were killed. This point is not as obvious as it seems. For example, warnings must do more than tell people that they should "get to high ground." High ground for some may be the low ground for others. High ground must be defined, for example, "ground higher than the top of city hall," or specify areas to which people should evacuate.

2.8 WARNING FREQUENCY

Eighth, frequency or the number of times the warning message is delivered affects hearing, understanding, believing, and deciding, and is thus important at most stages of response. Numerous studies underscore the importance of repeated hearing of a warning as a condition for response (cf. Fritz and Marks 1954; Drabek and Bongs 1968; Mileti and Beck 1975; Baker 1979; Turner 1983; Mikami and Ikeda 1985; Rogers 1985). The frequency of public messages should be referenced so

that people will be informed about when they will hear the message, or a new message, again. This information can reduce anxiety created by not knowing when one can confirm what is happening or learn more details. Frequent messages can also help reduce the effect of misinformation and misperceptions. There are some potential advantages of frequently recurring warning messages. Frequently recurring warnings (e.g., "This message will be repeated over this same station every fifteen minutes, unless new information updates are available") focus people on official warnings, reduce rumors, and increase public confidence in the validity of the warnings.

There is no magic formula for specifying how frequently a warning message should be repeated, but some guidelines can be established on the basis of knowledge about how the public processes warning information. In part, dissemination frequency is geared to the dynamics of the emerging risk and its severity, as well as being influenced by increased or changed knowledge about it. Frequency is best dictated by the needs of the public at risk. It is difficult to provide people at risk with too many warnings. People want updates of information even when there is little change in the content of the warning. In protracted emergencies, however, there is a point of diminishing returns after which messages that contain no new information may be counterproductive.

2.9 RISK LOCATION INFORMATION

Ninth is the specification of location effected by the message. Identifying a location is important in determining belief and personalizing a warning. The emergency warning information should clearly state the areas effected or potentially impacted by the event. People must be told if they are the intended recipients of the message or not. For example, Diggory (1956) showed that the closer the respondent's proximity to a threatened area, the more likely that person will believe the message. Other studies show that more location-specific messages lead to greater levels of personalized risk (Perry and Greene 1983; Nigg 1987).

Detailing the location of risk is best done in ways readily understood by the public. For example, a flash flood warning could say "The area of town that will flood will be between Second and Fifth Streets, from Elm Avenue to Magnolia Boulevard." If there is reason to be concerned that people who are safe could think that they are unsafe, then the warning should address them, for example, "People who live in other parts of the city will not experience flooding" but information like this should be followed by explanations of why they are safe. Addressing people who are not the targets for a warning is important since a wider audience than those at risk will hear the warning message.

2.10 CHANNEL OF COMMUNICATION

And, tenth, the channel of information plays an important role in warning response. Risk information communicated over multiple channels, such as printed and electronic media or personally delivered, has been shown to enhance hearing, understanding, belief, and response by a public at risk (cf. Mileti and Beck 1975; Flynn 1979; Turner et al. 1979; Carter 1980; Hiroi, Mikami, and Miyata 1985; Rogers 1985; Nigg 1987). Warnings can be issued to the public in a variety of ways, for example, by voice, electronic signals, or printed media. Voices can be direct or broadcast over loudspeakers, public address systems, telephone, radio, or television. Signals include sirens, alarms, whistles, signs, and lights. Leaflets, brochures, or video can be used to distribute graphic information and printed messages. Effective warnings use a range of possible channels

instead of a single channel. This helps reach as many people as possible in a short time.

3. RECEIVER FACTORS THAT INFLUENCE PUBLIC RESPONSE

Public protective actions in response to warnings of impending natural and technological disasters have also been shown to co-vary with the situational and personal characteristics of those who receive hazard warnings. These "receiver" characteristics fall into six general categories.

3.1 ENVIRONMENTAL CUES

First, environmental cues or physical characteristics of an emergency setting can interact with sender factors to convey information to receivers. The visibility of the hazard is a physical characteristic. It is difficult (or at least more difficult), for example, for the public to believe a flood warning on a sunny day, to heed an evacuation warning if neighbors are not seen evacuating, or to believe they are still at risk if volcanic ashfall has stopped. People often wait to evacuate in a hurricane until they see the weather change. Such environmental cues are important for understanding, believing, personalizing, and confirming the threat, as well as responding to the threat (cf. Drabek 1969; Mileti et al. 1975; Flynn 1979; Quarantelli 1980; Cutter and Barnes 1982; Saarinen and Sell 1985; Bellamy 1987; Rogers and Nehnevajsa 1987; Tierney 1987). It is, therefore, important when no cues exist to use an artificial means to break a routine-appearing environment. Sirens can help accomplish this. Location of the risk or geographical proximity of those at risk to the impending threat is another type of physical factor that affects belief and personalization (cf. Diggory 1956; Flynn and Chalmers 1980; Perry and Lindell 1986).

3.2 SOCIAL SETTING

Second, social setting factors characterize the context in which the emergency information is received. Such factors include whether or not the family is united when the warning is delivered, what activities are being performed at that time, and what others are doing to respond. Social setting factors affect beliefs, decisions, and response (cf. Clifford 1956; Moore et al. 1963; Dynes and Quarantelli 1968; Drabek and Stephenson 1971; Flynn 1979; Gutter 1987). Mack and Baker (1961), for example, reported that family unity at the time of a warning increases the likelihood of belief. Drabek and Stephenson (1971) noted that families who are united at the time of a warning are more likely to respond to the warning. The importance of family unity in evacuation decisions in human-made emergencies is substantiated by the Three Mile Island (TMI) accident in which only 10.6 percent of the sample of households had some members evacuating and some members staying. This means almost 90 percent of the households behaved as family units. In addition, neighbors and friends evacuating are major influences in decisions to evacuate. In an article by Cutter and Bames (1982), it was noted that, for some people at TMI, evacuation behavior was associated with knowing a neighbor had evacuated.

3.3 SOCIAL TIES

Third, recipients' social ties can affect decisions to respond to warnings (cf. Clifford 1956; Gruntfest 1977; Worth and McLuckie 1977; Mileti et al. 1981; Rogers 1985; Bellamy 1987). Perry (1979), for example, found that as family cohesion increased, the likelihood of evacuating in

response to a flood warning increased. This was also found for nuclear emergencies when Sorensen and Richardson (1983) found that knowing someone who worked at the utility that owned the TMI reactors was related to the decision not to evacuate during accident.

3.4 SOCIO-DEMOGRAPHIC CHARACTERISTICS

Fourth, the socio-demographic characteristics of the receiver, such as resources, gender, and socioeconomic class, can influence hearing, understanding, believing, personalizing, and responding (cf. Friedsam 1962; Flynn 1979; Turner et al. 1979; Perry, Lindell and Greene 1981; Yamamoto and Quarantelli 1982; Rogers 1985; Nigg 1987; Perry 1987). For example, older people were less likely to have heard the Rapid City flood warning regardless of the source of the warning (Mileti 1975). And, in an analysis of the TMI accident, Sorensen and Richardson (1983) found that older people were less likely to evacuate, which is consistent with other studies of the TMI evacuation. Gender has also been found to be related to warning beliefs in that women are more likely to believe a warning than men (cf. Drabek 1969. Turner et al. , 1981; Yamamoto and Quarantelli 1982). The basis for this association, however, is not well understood.

3.5 PSYCHOLOGICAL CHARACTERISTICS

Fifth, psychological characteristics of the receiver, for example, cognitive abilities, personality, or attitudes can also influence reception of a warning. Limitations in cognitive abilities to process information are a constraint to all people receiving warnings. Variations in that ability influence understanding and deciding (cf. Sims and Baumann 1972; Flynn 1979. Turner et al, 1981; Quarantelli 1980; Perry 1987).

Personality traits are also related to decision and behavior. The personality factor most investigated in reference to disaster warning response is "locus of control." Simply stated, people with an internal locus of control are very self-determined; people with an external locus of control are characterized by fatalistic views of the world (cf. Rotter and Mulry 1965; Rotter 1966; Strickland 1965; Davis and Phares 1967; Lefcourt 1976). Internal people tend to feel they have control over their lives and behavior, while external people feel their fate is in the hands of others. People with an internal locus of control are more likely to hear, believe, personalize, and respond to a warning than people with an external locus of control (cf. Dynes et al. 1979. Flynn 1979. Turner, et al. 1981; Lardry and Rogers 1982).

3.6 PRE-WARNING PERCEPTIONS

And, sixth, pre-warning perceptions play a role in hearing and decision making. The concept of selective perception refers to the tendency to filter information to conform to existing views. Without adequate emergency information, people may disregard warnings if their risk perceptions are already biased. Such pre-warning perceptions may also influence decision making (cf. Baker 1979; Flynn 1979; Livermore and Wilson 1981; Mileti et al. 1981).

4. NEEDED RESEARCH

- DIFFERENCES AND COMMONALITIES IN WARNING RESPONSE. The warning

response research that has been performed to date has been varied in method and approach. Each piece of research has focused largely upon one or some few of the many factors that affect response. Consequently, research is needed which takes advantage of the knowledge already accumulated but which goes several methodological, theoretical, and practical steps further. An integrated warnings systems research effort is needed to (1) use state-of-the-art knowledge to study factors that influence human response, (2) measure those factors in the same or functionally equivalent ways across a range of warnings events and hazard types to provide cross-event comparisons and hazard specific lessons, (3) determine common themes applicable in all warning events, and (4) allow research to be performed almost immediately after an emergency before warning response data become less reliable.

The specific purposes of cross-hazards comparisons should be (1) to determine common warnings system elements for all hazards, for example, hardware and technologies, emergency organization, and warning messages, (2) to catalog what common warning system elements can be used to reduce duplication of warning systems and to integrate cross-hazard warning systems, (3) to suggest what common warning system preparedness elements are likely to hold in emergencies for hazards not yet experienced, (4) to reveal hazard-specific elements of warning systems needed for use in preparedness for the full range of potential hazards, and (5) to systematically test and refine a theory of public warning response. Something is already known about each of these issues, but knowledge is far from complete, and some of it is based only on anecdotal evidence that remains to be analytically demonstrated.

- ADOPTION CONSTRAINTS AND INCENTIVES. The state of knowledge regarding effective warning systems is good relative to other human interventions, e.g., land use, engineered solutions, insurance, etc., to reduce losses from floods. However, this knowledge is not fully used. A research effort is warranted to determine the major incentives and constraints to adoption of warning system knowledge. This research should not be limited to floods, but should instead include all hazards for which warnings systems could be useful. The research should also address the full range of entities that could be involved in adopting findings; these include local, state, and national agencies as well as some private sector organizations that maintain warning systems. This research could do much to reveal why the high potential for setting up effective warnings systems for most hazards is being ignored or is under used. It could also produce insights on how planners could be encouraged to use existing knowledge. Finally, this research could include an assessment and cost-benefit analysis of existing warning systems to determine fruitful paths for cross-hazard integration of warning systems design and technology.

- THE ROLE OF PUBLIC EDUCATION. It is unclear how and to what extent pre-emergency public education affects the behavior of people in response to future warnings. It is intuitive to presume that public education had a positive impact on public warning response. Moreover, it is not clear what type of public education is the most effective. At present, we can only hypothesize about the topics which pre-emergency public education should address, as well as about the form a public education campaign should take. For example, it would be appropriate to now hypothesize that the most effective form of public education is education that is a continuing process, specific in content regarding the actions which people should take, and varied in approaches used to deliver the information.

  Research is needed to determine the relative effectiveness of alternative types of public

information and education on warning response. This research should include the range of education avenues (e.g., brochures, school curriculum, telephone-book pages, and public sings, to name but a few), and seek to determine when and why the provision of information actually does result in learning. Research should also study the range of topics that could be addressed in public education, including, for example, the hazards, appropriate protective responses, and emergency warning types and sources. The effort should discover whether differences exist on the basis of hazard types, experience, location, and so on. It is likely that the intensity of the public education effort would affect subsequent warning response. Consequently, this factor should be made to vary in the research design; this would probably require field experiments.

- WARNINGS FOR FAST MOVING EVENTS. Fast-moving events pose unique public warning and response questions. We know too little about the unique needs for public warnings for such events to offer conclusions with confidence. No warning response study has been conducted on an event with less that 30 minutes response time. It has long been known that most members of the public seek additional information and interactions with others after receiving a warning and before taking an action such as evacuation. Yet some emergencies are so fast-moving that seeking additional information leads to increased losses. We also need to focus on the social psychology present during fast-moving events. This research should produce findings that would enable endangered publics to make quicker protective actions decisions in response to fast-moving events. The existing empirical research record does not include many such events, for these have been historically infrequent.

  Research into fast-moving events should be cross-hazard, including events like flash floods and chemical spills during train derailments and should seek to generate generic cross-hazard principles as well as unique hazard-specific findings. Particular attention should be paid to how pre-emergency education and disaster warnings could help the public perform alternative protective actions to evacuation, for example, sheltering in-place.

  Effective public response to fast-moving events requires that the hazard be quickly detected and that the public can be informed rapidly. Constraints may inhibit this process, and each should be researched. One of these constraints deals with the hardware of public alert. Research should address alternative schemes for alerting endangered publics: sirens, telephone systems, and the like. Second, in fast moving events the processing of hazard information in the detection and management components of warning systems must be streamlined. Retrospective studies of recent events and studies of events as they occur could help uncover procedures that would help reduce the time needed to process risk information prior to the issuance of public warnings to the bare minimum. Third, technical research is needed for some hazards to determine what the risks of public exposure are. For example, it may not be clear what are the risk scenarios nor range or efficacy of alternative protective public actions regarding the immediate release of, for example, secondary hazards such as nerve gas or other chemicals in floods. This information can assist planning. Finally, research on the efficacy of pre-emergency public education for special fast moving events could help reduce the time needed for public response. For example, the application of research findings in this arena could possibly reduce the time the public would ordinarily spend seeking confirmation of warnings received.

- WARNINGS FOR CONCURRENT HAZARDOUS EVENTS. A three-pronged research effort is needed to fill gaps in knowledge regarding warning system planning for concurrent

hazardous events.

First, physical science and statistical studies should be directed toward cross-hazard assessments to topologies probable concurrent hazards for linked hazards (one causes another) and for independent hazards (both coincidentally occur at the same time). This ranking would provide an informed basis on which to judge, which concurrent events should be planned for and which are best ignored. This effort need not be elaborate, but a systematic assessment by an interdisciplinary team of experts is needed in order to inform planning for concurrent hazardous events.

Second, planning and response experts should share judgements to produce a systematic catalog of warning planning needs for concurrent hazards. This assessment could detail generic and unique issues specific to unique hazards or sets of concurrent hazards.

Third, prototype plans should be developed in some localities that can be transferred to others. This three-step research process (based on physical science, planning and social science, and plan development) is sequential, is predicated on existing knowledge, and promises payoff.

- MEDIA ROLE IN WARNINGS. In emergencies, key media actors often intervene between those who have accurate information and the public. The media are the gatekeepers of most public risk information and warnings. The use of an Emergency News Center helps standardize information and fully inform the media in emergencies. Despite the important role of the media in warning systems, however, few studies have been performed on the media; and we have done too little to bring the media into the warning system preparedness effort. It is appropriate to proceed with at least two studies of the media in reference to warnings systems. First, it would be useful to gather data on how the media presents emergency information to the public during warnings. This study should assess media public information output from the viewpoint of factors demonstrated to have an impact on public response, e.g., frequency, clarity, and so on. Such a study would provide information regarding the final communication link in warning systems between the media and the public. Second, it would be useful to explore the most effective way to inform media of the factors important to keep in mind when performing a role in a warning system.

- IMPROVING COMMUNICATIONS. Warning systems are communication systems linking a variety of organizational actors to each other and then to the public. Therefore they involve communication devices and systems. Some of these are technological, such as dedicated phone lines, sirens, radios, and tone-alert radios. Others are behavioral, such an informal notification. The effectiveness of a warning system is dependent on systems such as these that constitute the "hardware" of a warning system. Few planning efforts for warning systems have taken stock of the full array of communication systems on which a warning system depends, considered back-up means of communication, or addressed updating communication technology. It would be appropriate to assess the alternative efficiency and effectiveness of available means of communicating and explore how adoption constraints could be removed.

5. SUMMARY AND CONCLUSIONS

Research over the last several decades has addressed public warning response in a wide array of climatological, geological, and technological events. Studies have been of various types;

some have been descriptive, whereas others tested hypotheses. Some have used sophisticated multivariate analysis whereas most have been content to explore the character of a few hypotheses based on simple statistical tests of correlation and significance. Enough evidence exists to conclude that it is imprudent to presume that all members of a public hear a warning just because one is issued, and the literature clearly shows that both sender and receiver/situational factors influence hearing a warning.

The research record points out the characteristics of warnings that maximize the probability that they will be correctly understood, believed, personalized, and acted on. The most effective warnings are those that are specific about impact location, protective actions to take, the time to impact, and the character of risk. Additionally, the most effective warnings are consistent and certain, address why they should be acted on, delivered through multiple channels of communication, repeated frequently, and labeled as coming from a panel of officials, scientists, and experts credible for everyone.

People respond to warnings through a social psychological process. Planning for a sound public response to future emergencies means that this social and psychological process must be understood by those involved in the warning process and addressed by those who plan for the possible dissemination of warnings to an endangered public in the future. Which persons in an endangered public do and do not hear, understand, believe, personalize, and respond to emergency warnings is not the result of chance. The sequential steps in the warning response process are the consequences of the effects of the risk message and the personal/situational characteristics grouped into the categories of receiver and sender factors.

Clearly, then, effective public disaster warning is a process and not an act. Communications that result in more accurate public perceptions of risk and public behavior in proportion to the risk that is faced typically have been comprised of multiple communications, arranged in a programmatic format, that take a variety of communication variables or factors into account, for example, source, consistency, accuracy clarity, certainty, guidance, frequency, location, communication channel, and so on. Public warning response is best understood and planned for if it is viewed as a series of related sequential factors: hearing warnings, understanding what is said, believing what is heard, personalizing what is believed as may be appropriate, deciding what to do, and then engaging in response behavior.

Receiver characteristics vary widely among members of a public in any one warning circumstance, as well as between different events. In warning events that provide convincing and reasonable emergency warning information to the public, the understanding, belief, personalization, and response of the public can be sound. The effects of receiver determinants on warning process outcomes are not unchangeable laws of nature. It is possible to design a warning system with sender characteristics that maximize the probability of sound public response and also minimize the negative impacts of some receiver characteristics. Warnings that result in more accurate public perceptions of risk and public behavior in proportion to the risk that is faced typically have been comprised of multiple communications, arranged in a programmatic format, and provide the full range of communication variables discussed above to the endangered population.

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