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Public perceptions of U.S. earthquake early warning post-alert messages: Findings from focus groups and interviews

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ABSTRACT

In May 2020, a false earthquake alert message was sent to the city of Ridgecrest, CA, in the U.S.A., an area that just 10 months prior had experienced a significant series of earthquake events. The false alert was followed by a post-alert message, indicating that the message was cancelled and under investigation. This event, the first of its kind in the U.S.A., provided an opportunity to learn about public perceptions of the post-alert message, including what individuals understood about the threat and their safety, and what actions they should take as a result. We conducted individual interviews with 40 persons in the Ridgecrest community, followed by a series of focus groups in Southern California to discuss post-alert messages, and to learn about information people most needed following false earthquake alerts. We found that individuals with and without prior earthquake experience expressed confusion about content describing the investigatory actions of the organization and had a largely negative response toward content that complimented those who took action in response to the initial earthquake early warning. While current post-alert messages are intended to reinforce the good intentions of the organization and the protective actions taken by message receivers, the message issued was perceived by members of the public to be largely ineffective in achieving either objective because it did not provide the information they desired most—an explicit statement about their safety. Instead, message receivers need information that primarily affirms their current level of safety so they can return to normal functioning.

Keywords: earthquake early warning, post-alert message, cancellation, alert, warning, earthquake

1. INTRODUCTION

Hazard warning messages are sent with the intent of motivating protective action in response to a threat that places the message receiver at risk for a limited duration of time. In many cases, such as with weather related hazards, a warning message will *expire* with the passage of time and changing environmental conditions (see National Weather Service 2022 for examples). In some cases, however, messages will be *actively cancelled,* such as when the threat is no longer a risk to personal safety and the situation is clear for the message receiver to return to normal activities (National Weather Service 2022; TMJ4 Web Staff 2022). Occasionally, a message must be cancelled due to situational or contextual reasons, such as when it has been sent unintentionally, distributed to a population that is not at risk, or resulted from a failure in the warning system or process. In 2018, for example, a warning message for an incoming missile was sent to cell phones in Hawaii. While the ICBM message was a result of human operator error, it took more than 38 minutes for the Hawaii Emergency Management Association to send a follow-up cancellation message (Federal Communications Commission 2018). Under each of the conditions described, a post-alert cancellation or "all clear" message delivered to the originally notified populations has the potential to relieve concerns about the initial threat and encourage a return to prior conditions.

Knowing that warning message error or system failures are possible, one agency, the United States Geological Survey (U.S.G.S.), has created post-alert messages in advance to address various conditions of concern (McBride et al. 2020); other organizations have also been encouraged to do so (see Federal Communications Commission 2018). The development of pre-event messaging templates, as with all warning messages, will reduce the time needed to design and disseminate such messages, alleviate the distress potentially caused by the original alert (DeYoung et al. 2019), and potentially limit the drain on emergency management resources as calls flood public safety answering points (PSAPs) to inquire about the ongoing danger and current risk (Peterson et al. 2019).

While planning for and developing post-alert messages can enable these positive outcomes, there is limited research on public perceptions and responses to such messages. Furthermore, there is limited research on message design targeting how to effectively communicate that a situation is "all clear." Research from the field of crisis communication points to organizational strategies (who speaks when, and the most effective position or stance to take in the given circumstance) that can affect organizational trust, reputation management, and image repair (Coombs 2021; Reynolds and Seeger 2005; Sellnow et al. 2017). Nonetheless, we are not aware of empirical studies that focus on the content of cancellation *messages*.

In this paper we focus on building an optimal post-alert message by drawing upon research with members of the public following an earthquake early warning cancellation. This research is informed by two Phases: Formative research in Phase 1 draws from interviews in response to a post alert message developed by the USGS ShakeAlert Joint Committee for Communication, Education, and Outreach (JCCEO) that was sent following a false earthquake early warning (EEW) event. In Phase 2 we build upon this formative research and conduct a series of focus

groups that consider a set of alternative post-alert messages. We find that post-alert messages that focus on message cancellation and organizational response activities do not directly address the concerns that are shared by members of the public, leading to limited understanding of personal safety. Based upon these findings, we propose a design that is responsive to public information needs and suggest avenues for future research.

2. LITERATURE REVIEW AND THEORY

Earthquake early warning (EEW) is a fairly recent addition to U.S. warning system arsenal (Earthquake Hazards 2022). This technology does not enable earthquake prediction, but rather detects earthquake shaking before it is felt and can provide seconds to tens of seconds of warning to populated areas. ShakeAlert makes it possible to provide enough warning that the public can take self-protective action before heavy shaking arrives, with potential benefits including the ability to reduce death and injury, mitigate property and infrastructure damages, and increase community resilience by reducing long-term economic loss. The system is currently operating along the U.S. West Coast, in the states of California, Oregon, and Washington.

Scholars and practitioners who were invested in the successful launch and maintenance of earthquake early warning advocated for post-alert messaging as the ShakeAlert automated system was rolling out, in 2018. Because ShakeAlert relies upon the accurate execution of environmental sensing, monitoring, modeling, and predicting in a seamless manner, there is potential for mislocated events (Kohler et al. 2020), technological malfunctions, and system or modeling errors (Minson et al. 2017). Given this potential for error, there exists concern that early alerting mishaps may lead to reduced trust in the message source organization, credibility in the automated system, and likelihood that people will heed the recommended actions when it matters the most.

While there is a rich history of research on false alerts, much of this work focuses on concerns about over-alerting, that is when an individual receives too many messages or messages that are beyond the boundaries of the threat (Trainor et al. 2015), and how this may result in the phenomena of “crying wolf” (Sorensen and Sorensen 2007). The primary concern related to over-alerting and crying wolf is that over time, people will become desensitized to warnings, message receivers will cease to react, and the messages will no longer have the desired effect, which will then impair warning-related decision-making and behavioral responses (Mackie 2014). These concerns also bear on public trust and willingness to rely on an organization that may be perceived as issuing messages that are inaccurate or inconsistent.

These concerns about false alerts were prominent in some of the earliest thoughts about the feasibility of an automated earthquake early warning systems (Tierney 2000). Foresight into potential problems and the associated liabilities associated with automated EEW systems has influenced the design of post-alert messages to reduce the likelihood that members of the public will ignore or turn off future earthquake alerts, while helping to recover trust in the organization, the system, and willingness to take action when it is recommended.

To date, only one false earthquake alert has been issued. This alert, sent to the community of Ridgecrest, CA in May 2020, was the result of a mislocated system test message that was sent to a population that happened to have previously experienced a significant earthquake event during the prior year (Salahieh 2020). The false alert was followed by a post-alert message, providing a unique opportunity for researchers and practitioners to learn about the lived experiences and perceptions of members of the public in the context of a highly uncertain environment in which they received a follow-up message intended to support and explain a prior false alert.

Post alert EEW messages were initially designed by U.S.G.S. to take into consideration three elements:

1. The status of the message or the earthquake;
2. What the organization is doing in response to the alert; and
3. Reinforcement of or support for protective actions that message receivers may have taken (McBride et al. 2020; see Table 1, USGS Post Alert Messages).

The first element, the status of the message or the earthquake, is drawn from research on the contents that increase the likelihood that individuals will change their behavior in response to a warning message (Mileti and Sorensen 1990). These include contents about the hazard and its impact, the location of the hazard, the actions necessary to protect oneself, the time by which to take those actions, and the name of the message sender or organization (Mileti and Peek 2000). The status and characteristics of the threat are important to relay as individuals assess the risk, its severity, and their personal susceptibility to the threat and its impact (Maddux and Rogers 1983; Rogers 1983).

The second element, focusing on organizational response, is drawn from research on organizational crisis communication, specifically the Crisis and Emergency Risk Communication (CERC) model (Reynolds and Seeger 2005). The CERC model identifies key points for crisis communicators to address at varying times along the crisis continuum timeline. In particular, the model notes that organizations should inform message receivers, stakeholders, and constituents about the organization's actions to investigate and address how a crisis initiated, how it is being managed, and how they will continue to monitor and update affected individuals (Reynolds and Seeger 2005). In doing so, the authors explain, organizations can help to reduce attribution of blame and maintain trust in their ability to manage the event and its outcomes.

The third element, focusing on affirming protective actions that were taken in response to the warning message, is drawn from research investigating public responses to earthquake drills (McBride et al. 2019). In post-drill surveys and interviews, participants described their reluctance to take the recommended actions of "drop, cover, and hold on" due to ambulatory challenges and concerns or fears about appearing foolish (Becker et al. 2016; McBride et al. 2019). The reinforcement of correct actions could encourage message receivers to act in the future by engendering positive social norms (Vinnell et al. 2021).

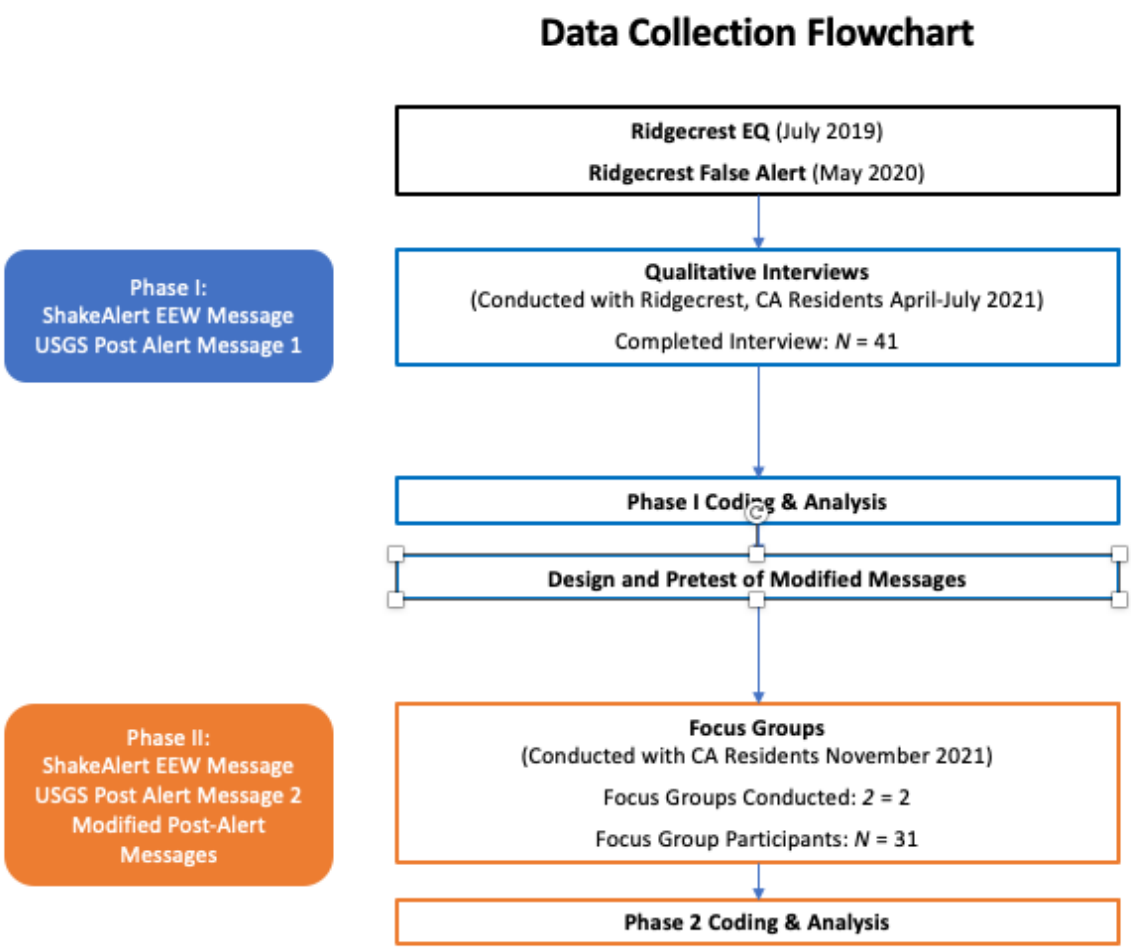
To date, there has been no research examining perceptions of EEW post-alert messages, underlining the need for understanding and evaluating the effect of alternative content and delivery approaches to post-alert earthquake messaging on perceptions and behaviors among members of the public. This research is urgently needed to help practitioners optimize future messages delivered post-event. In this two-part study, we conducted a series of interviews with individuals who received a post-alert message in a real-life context, followed by focus groups conducted with persons who evaluated the content included and language used, and then made suggestions on how to improve future post-alert messages.

The overarching research question for this qualitative study was, *"What is the best content and language to include in a post-alert message?"* Although this research was focused on earthquake early warning, the results of this study may provide valuable insight that may be applied to other hazard contexts.

3. MATERIALS AND METHODS

We conducted qualitative personal interviews in Phase 1 of the study, and focus groups with a separate sample in Phase 2, to explore how people understand and react to a variety of earthquake post-alert messages (see Figure 1). Personal interviews and focus groups, alike, used volunteer samples and were conducted via Zoom teleconferencing software. As part of the individual and group interviews, participants viewed, considered, and discussed an original "false alert" message as well as a series of revised post-alert messages following an earthquake early warning.

Figure 1. Flow chart showing phases of qualitative research used to investigate EEW post-alert messages.



3.1 Stimuli

During Phases 1 and 2, participants viewed and discussed three kinds of messages: 1) the ShakeAlert earthquake early warning message; 2) two original post-alert messages (McBride et al. 2020; ShakeAlert 2021), and 3) six modified post-alert messages. All messages conform to the character limitations found in the Wireless Emergency Alert service (a maximum of 90-characters). The ShakeAlert EEW and USGS post-alert messages used in Phases 1 and 2 are presented in Table 1. The modified post-alert messages, used only in Phase 2, are presented in Table 2.

#	Message Stimulus	Viewed by
	ShakeAlert EEW Message	

1	Earthquake! Expect shaking. Drop, Cover, Hold On. Protect yourself now. – USGS ShakeAlert	All interview and focus group participants
	USGS Post-Alert Messages	
1	USGS ShakeAlert message cancelled. Investigating. If you protected yourself, well done.	All interview participants
2	USGS ShakeAlert Message requires investigation. If you protected yourself, well done.	All focus group participants

Table 1. Interview and focus group message stimuli: ShakeAlert EEW and USGS post-alert messages.

The ShakeAlert EEW message is a real message that is currently issued by ShakeAlert and was received by the Ridgecrest, CA population as a false alert. The two USGS post-alert messages also are real messages. The first message was sent by USGS following the Ridgecrest false alert; the second is designed to be sent following future EEW false alerts (ShakeAlert 2021).

The six modified messages (see Table 2) were designed by the research team and varied in four ways: first, we varied the name of the source sending the message; modified messages 1 and 4 include the name "USGS ShakeAlert," while messages 2, 3, 5, and 6 reference a more generic "earthquake alert." Second, we varied the status of the message; messages 1, 2, and 4 are "no longer in effect" or "expired," referencing a routine or time related ending of the message, whereas messages 3, 5, and 6 are actively "cancelled" or "recalled," referencing actions taken by an organization to end a message. Third, we varied the inclusion of an explicit explanation for the given message status; messages 1 - 4 provide no explanation for ending the message, whereas messages 5 and 6 include the update that "no shaking [was] detected" or there was a "processing delay." And fourth, we varied the inclusion and orientation of protective action guidance. In contrast with the original USGS post-alert messages that reinforce protective actions that were previously recommended, messages 1 - 4 include future oriented guidance "remember" or "when alerted," while messages 5 and 6 do not include guidance.

#	Modified Message	Source	Message Status	Explanation	Protective Action	Viewed by
1	USGS ShakeAlert Message no longer in effect. When alerted, drop, cover, and hold on.	USGS ShakeAlert	No longer in effect	None	Future-oriented guidance	Focus groups 1, 3, and 5
2	Earthquake alert no longer in effect. When you receive an alert, drop, cover, and hold on.	Generic	No longer in effect	None	Future-oriented guidance	Focus groups 2, 4, and 6

3	Earthquake alert cancelled. When alerted, remember: drop, cover, and hold on	Generic	Cancelled	None	Future-oriented guidance	Focus groups 1, 3, and 5
4	USGS ShakeAlert Message expired. When alerted, remember: drop, cover, and hold on.	USGS ShakeAlert	Expired	None	Future-oriented guidance	Focus groups 2, 4, and 6
5	Earthquake alert cancelled. System error, no shaking detected.	Generic	Cancelled	System error	No guidance	Focus groups 1, 3, and 5
6	Earthquake alert recalled. System error due to processing delay.	Generic	Recalled	System error	No guidance	Focus groups 2, 4, and 6

Table 2. Focus group message stimuli: modified messages.

3.2 Participant Recruitment and Demographics

3.2.1 Phase 1: Interviews.

Forty-one interviewees were recruited via a posting to Facebook community groups for the local geographical area or Ridgecrest, CA and received a $25 gift card as an incentive for completing the interview. Social media recruitment strategies are frequently used to narrowly target populations that have experienced local events, allowing for self-selection of participants willing to talk about their experiences (see DeYoung et al. 2019; Mongold et al. 2021). Of the 41 interviewees, about 34% identified as a man and 66% as a woman. Participant ages ranged from 20-70 years, with 50% being under age 40. Participant length of residency in Southern California at the time of the interview ranged from 2 to 66 years (average of 29 years). Interviews took place via Zoom between the months of April and July of 2021, and ranged from 26 to 99 minutes in length (average of 47 minutes).

3.2.2 Phase 2: Focus Groups.

Thirty-one participants who were residents of California and at least 18 years of age were recruited for focus groups via an advertisement on Facebook targeting to persons in San Francisco and Los Angeles, CA. Participants received a $25 gift card as an incentive for completing the focus group interview. Of the 31 participants, 38% (*n* = 11) identified as women, 24% (*n* = 7) identified as black or African American, 14% (*n* = 4) identified as Hispanic or Latinx, and 10% (*n* = 3) identified as Asian. The youngest participant was 22 years of age. The oldest did not report their exact age but was over 65 years old. The median age was 25 years. Interviews took place via Zoom in December 2021 and were an average of 60 minutes each in length.

3.3 Data Collection

3.3.1 Interviews.

After consenting to the interview, the lead interviewer introduced an initial topic designed to establish rapport and recall participants' memories of the event. Specifically, the interviewer asked participants to describe memories of their experiences in response to the earthquake sequence in July 2018 and also the false and post-alert messages sent in May 2019. The interviewees were then shown the earthquake early warning message (see Table 1) and were asked to comment on their overall impression of the message, including things that caused confusion, and then to define what specific words or concepts within the message meant to them. A second researcher took notes throughout the interviews. This same process was completed with post-alert message 1 (Table 2).

3.3.2 Focus Groups.

After consenting to the focus group interview, the focus group moderator shared an image of the earthquake early warning followed by post-alert message 2 (Table 1). Participants were asked to comment on their overall impression of each message, including anything that caused confusion, and to define what specific words or concepts within the message meant to them. The moderator then explained the various conditions under which a post-alert message might be sent, such as a mislocated alert where shaking occurred, but the area receiving the alert was not affected; an accurate alert, but shaking was not strong enough to warrant an alert; or due to another inaccuracy of the system. The post-alert message was discussed a second time. The moderator then shared images of three modified post-alert messages (Table 2). Three groups reviewed messages 1, 3, and 5; three groups reviewed messages 2, 4, and 6. Messages were first viewed one at a time, and then side-by-side. Participants were asked to comment on each message and to identify the message that would best address their concerns or questions about the initial earthquake early warning.

All interviews and focus groups were audio- and video-recorded. Audio files were digitally transcribed via Zoom at the time of the interview, later checked for accuracy, and then stored as Word documents. The research team used spreadsheets to organize interview and focus group contents based upon questions posed.

3.4 Data Analysis

Among the authors, a coding team was formed and met together for multiple sessions where members jointly identified variation in responses to each question, noting the consistent use of words or phrases and quantifying their use when possible. Once qualitative data were coded, the lead author organized contents into thematic groupings (Creswell and Creswell 2017). The writing team discussed these groupings and categorized them, taking into account their relationship to theory on warning response and crisis communication. Thus, there were multiple levels of review in the development and confirmation of codes (Creswell and Miller 2000).

4. RESULTS

4.1 Interviews

Interview participants discussed the earthquake early warning (Table 1) and the USGS post-alert message 1 (Table 1). We present those findings next, organized by message variation.

4.1.1 EEW message.

Interviewees consistently noted that the EEW was extremely brief and therefore was missing information that would help them to understand the threat, its severity, the location, and when to act. One interviewee summed it up by saying, “It didn’t say where it was expected, whether it was [expected], what the timeframe would be, whether it was an immediate problem. I don’t know how localized it was.”

4.1.2 Post-alert message 1.

Interviewees had mixed understandings about *what* was cancelled. Nearly half of the interviewees discussed the conditions leading to the cancellation message saying the earthquake was not going to happen, no longer happening, or no longer an emergency condition. Some explained that the word “cancelled” referred to the message itself in relation to a potential earthquake. For example, as one interviewee explained:

> *[Cancelled means to] Disregard the previous message. I wonder why, but for whatever reason disregard. I guess cancelled isn't 100% clear. That “Okay it's cancelled,” does that mean an earthquake actually happened and wasn't near me? Or was this just sent 100% in mistake? It didn't quite tell me how I should treat the first message other than just ignore it. Just saying cancelled doesn't really tell me, should I not be worried about further earthquakes that day. It doesn't completely make me feel like I could stand down.*

For some, the timing of the post alert message caused confusion and they wondered why it was important to cancel a warning 45 minutes after an initial warning had been sent. Noting that the post alert message would be delivered with the same alerting tones as the initial earthquake early warning, a noise described by some as being quite “jarring,” one person commented with apparent frustration that the post-alert message was “a *warning* message to *warn* me that the last *warning* is cancelled.”

Many interviewees interpreted the word “investigating” as a statement that “something went wrong.” For most interviewees, this created an air of mystery and intrigue and led to additional questions and speculation. Some interviewees surmised that the investigation might focus on why the earthquake did not happen; why the message was sent (perhaps mistakenly); or what consequences might befall the sender of the message. One interviewee offered the following reflection:

> *My training experience tells me that someone screwed up and they're investigating what happened. To the layperson that could be that they're investigating the earthquake or why didn't the earthquake happen. That's a very nebulous word in this case. They need to explain that a little bit more.*

However, two interviewees suggested that the investigation was focused not on the earthquake or the alerting system, but on message receivers themselves. An investigation would determine what kind of behaviors they had taken in response to the earthquake early warning message. One interviewee referenced a significant earthquake that had occurred the previous year and said the following:

> *They're investigating if we protected ourselves? I'm sorry, did you think we didn't learn from the 7.1? The 7.1 changed everyone in town. We don't look lightly at the shaking anymore, so we found this rather insulting.*

Interviewees were then asked to describe their response to the phrase, "If you protected yourself, well done." Four response types emerged. Most interviewees (*n* = 13) explained that the tone of the message was patronizing and condescending; one even described it as feeling like the message sender was "talking down" to a child, saying,

> *I think it's a little condescending. I think it's a little like "here's a pat on the back." Like "here you get a lollipop." I think it's a little silly. I don't think it's appropriate for an emergency alert. It's like my second graders how we just did a fire or earthquake drill. I'm like "well done everyone, let's go play now, like good job."*

A second group of interviewees (*n* = 10) thought the inclusion of the phrase was not well considered, especially in light of prior earthquake experiences, and believed its inclusion in the message was unnecessary. One explained:

> *It's extremely unnecessary and almost insulting. If it happened in July [after the previous earthquake] I might have had a different attitude. It's something you do to children. Almost humorous what they're trying to do with the "well done" thing. But the humor is kind of lost when someone actually goes through it. A lot of people [were] stating that it made them upset and it wasn't funny, which now has made everyone dismiss them in the future. It's almost joking.*

A third group of interviewees (*n* = 7) found that the use of this phrase added a bit of lightness to the message, which was a "nice touch" as it affirmed message receivers who took action and made the message more personal.

> *That was a slightly personal way to say it that wasn't all governmental. I feel like there was a human being behind it who said, "well tell them they did a good job if they protected themselves."*

And, finally, a few interviewees expressed concern (*n* = 2), saying that the message was "passive-aggressive" and condemning to those who did "the wrong thing."

> *My brain finishes this message "and if you didn't protect yourself, you're an idiot." What the hell? Why are you saying that?*

4.2 Focus Groups

Focus groups participants discussed the earthquake early warning and USGS post-alert message 2 (Table 1) and the modified post-alert messages (Table 2, messages 1-6). We present those findings next, organized by message variation.

4.2.1 EEW Message.

While focus group responses to the earthquake early warning were largely consistent with interviewees, their prior experience with earthquakes and earthquake early warnings differed. Many focus group participants were new to the area or lacked recent earthquake experience, and therefore had limited knowledge of how earthquakes "work" and what actions to take when shaking begins. For example, while many focus group participants agreed that the message seemed urgent, saying, for example, "This feels like it's going to happen any second now," their unfamiliarity with earthquake phenomena and protective actions were summed by one interviewees comment, "I would have no idea what I was doing. Hold on to what? Cover what? Drop?"

Most questions, however, focused on how the earthquake early warning *system works*. For example, participants asked, "What's the criteria? Who makes the decision when it goes out? Is it ten, thirty, or sixty minutes before? Who monitors it day in and day out? When does it go out?" They also asked where the system is operational and which geographical areas would receive a message ("A particular county or state? Nationwide?") as well as whether the message was tied to an app on the person's cellphone, alerting them even when they were not in danger. Others wanted practical information related to the earthquake conditions, such as where the earthquake was located, when the shaking would arrive, and how strong it would be. One participant with mobility concerns explained their hesitancy to act, saying:

> *Where is it and how strong? I've been through a lot of earthquakes. Most of them I don't even get out of my chair. Do I want to bother getting out of this chair? How bad is it? How close to the epicenter am I? How serious will it be?*

4.2.2 Post Alert Messages.

In response to USGS post-alert message 2, many focus group participants struggled with the phrase "requires investigation." Some wondered if the investigation was focused on the earthquake, asking if there might be aftershocks, or the message, linking the statement "requires investigation" to a feeling of lacking confidence in the system. For example, one person said "huh? What am I supposed to do with this? It decreases my confidence the next time I get an alert." However, some asked about the potential reasons an investigation would be required, suggesting that it could be due to "sabotage to our warning system," "a fraud," "spam," a "malfunction of the system," or a "mistake." Most participants did not comment about the statement reinforcing protective actions, "If you protected yourself, well done"; only two participants commented about the phrase, saying that it felt a bit condescending.

The first modification to the post-alert message was to vary **how the message source was named**, either as USGS ShakeAlert or as a generic system-generated message. When participants viewed three modified messages side-by-side, none noted the inclusion or absence of the name of the message source.

The second modification to the post-alert message was to provide the **status of the earthquake early warning**, explaining that the message ended in a routine manner (no longer in effect or expired), or was actively cancelled or recalled by the organization. Very few comments were made about the language used to describe the message status, and those centered on the use of the phrase "no longer in effect." One participant said, "I favor 'no longer in effect,'" explaining a preference for this because it was familiar:

> *It's exactly like weather warnings. No longer in effect regardless of whether a tornado occurred or not. There was a watch issued – if you had a tornado or not, we are now ending the watch. Perhaps the alert was called for another area but didn't affect me.*

In contrast, two interviewees found this phrase "too wordy" or "too hard to understand."

The third modification was to provide an **explanation** for the earthquake early warning message status—either as a system error related to shaking detection or a processing delay. While several participants had positive responses to the explanation provided for the cancelled message, many found the added explanation to be troubling. For example, one person said that the explanation would "give people reason to doubt; they might think the next message is an error," and another agreed, "I will not trust these [earthquake early warnings] after receiving such a message." One person argued with the accuracy of linking the idea of a "system error" with the explanation that "no shaking has been detected," saying "it detected something so it's not an error; it just didn't pan out the way they thought it would."

And finally, the fourth modification was to include **future-oriented protective action guidance** in messages. While most participants did not comment on the protective action guidance, one remarked that the message should be more specific about *when* an alert might be sent, such as "for future alerts," instead of "when alerted." This respondent remarked that, "now I'm going to be sitting by my phone for the next hour thinking the next alert is today or the next hour. Make it more time relative." Another said they appreciated the recommendation to "remember" saying, "I like the statement. 'When alerted, remember.'" Explaining that "this time [the message] is over, but at some time in the future, remember to act."

One common response to each post-alert message viewed by the participants was a frustration that the post-alert did not address their core concern of safety. As one person put it: "the real issue is that I'm safe." This was echoed over and over again as participants stated that a post-alert message should not focus on comforting people, explaining about the system and what worked or didn't work, or what the organization is doing to investigate, instead, they wanted to know "am I still in danger," "is the event over," and "how does this pertain to the safety and security of those around me?" Several argued that what they want is a message stating the situation is "all clear."

While one person explained, "there is of course no all-clear. We don't know that there's not about to be a huge quake in the area," others said they prefer a message stating that "no further action is required" or "the incident has passed." For those who expect that they will take action in response to an earthquake early warning in the future, they also want to know if it is safe to come out from underneath the table.

5. DISCUSSION

This study investigates perceptions of post-alert messages designed to follow the issuance of an earthquake early warning. We report the findings from interviewees who had previously experienced a local earthquake as well as a false alert, followed by a post-alert message and the findings from focus group participants with considerably less prior earthquake experience and knowledge of earthquake early warnings. In both cases, participants provided consistent responses to the initial warning message. In response to the earthquake early warning, they requested more information about the threat, its timing, and location and had questions about how the system works, and under what conditions a message might be sent. These comments suggest that absent changes to the channel that would allow for greater message specificity, public education about ShakeAlert and other earthquake early warning systems will be key to increasing knowledge, trust, and willingness to act when a message is received.

Participants in both phases of the research also provided consistent reactions to the original post-alert messages (see Table 3 for a summary). The inclusion of information about the organizational action being taken following the initial alert (i.e., the word, "investigating") was confusing to message receivers, raising alarm about the organization serving as the message source and also about the warning system, itself. The statement reinforcing protective actions (i.e., the phrase, "well done") was described by some as being condescending and trite, and by others as a passive-aggressive means of criticizing those who had *not* taken action. Both negative reactions contradict the intended purpose of including the language—to make those who took protective action feel good about having done so, and to remind those who did not take protective action about what they should do when they receive an EEW in the future.

Message Content Type	Language Preferred by Participants	Language NOT Preferred by Participants
Source	No preference stated	No preference stated
Message status	No longer in effect	Cancelled; Expired; Recalled
Message Explanation		Investigating; Requires investigation; System error
Protective Action Statement	When alerted, remember	Well done; When alerted; When you receive an alert

Table 3. Summary of Participants' Reactions to Earthquake Post-Alert Message Wording

In addition to the initial messages, focus group participant responses to the modified messages were found to be rather negative as well. Comments on the source of the message were made infrequently and the variations on the word "cancelled," (expired, recalled, and no longer in effect) were limited primarily to concerns about message length. The inclusion of an explanation for the cancellation (e.g., system error), in contrast with the more ambiguous language, "investigating," resulted in concerns about whether the system could be trusted to be accurate in the future. And overall, participants were consistently stymied by the fact that none of the messages included what they needed most: a reassurance of safety.

Notably, one can never be absolutely certain there is no present earthquake threat; historical examples such as the indictment and imprisonment of scientists and risk communicators following a false statement about safety following an earthquake in L'Aquila, Italy show the dangers of providing such reassurance (Alexander 2014) when future shaking is unknown. Scientists' concerns about providing false statements of safety, even when probabilities are extremely low, must be balanced by publics' fears of remaining at risk. In the case of a false alert, organizational vulnerabilities are exposed because the next period of shaking can never be predicted. This leaves message receivers in the unenviable position where, once alerted, they will remain in a continuously heightened state of risk. The question becomes how to best address the current threat while recognizing future events remain possible. One way this might be accomplished is by noting that the event referenced in the warning has concluded, and that future aftershocks or other larger earthquakes remain possible. Additional research on how to best balance individuals' desire for information about current safety with the inherent challenge of communicating their complicated and somewhat uncertain safety status is needed.

6. CONCLUSIONS

6.1 Limitations

Because only one false alert event followed by a post-alert message has been experienced in the US to date, a qualitative research approach using focus groups in individual open-ended interviews was used to explore participants' understanding of and response to the post-alert message. The 40 interviewees with this prior experience represent a narrow subset of the US population, but the experiences they shared provide important insights to message writers about how people understand such messages. Likewise, the focus group participants, which included 21 persons from two regions of California, are not generalizable to the broader public. As our nation gains more experience with post-alert messages, future message testing using quantitative methods and representative samples will be able to address quantitative questions about the frequency of different types of responses and perceptions related to post alert messaging for earthquakes and other hazards. In addition, we recognize that the messages designed for this study represent only a handful of options, and that none fully implement the guidance from the warning response model. Some of these challenges are also due to the limited character count of an EEW sent via Wireless Emergency Alert. Until messages are expanded to include the full 360-characters that are now allowable, post alert messages will remain extremely brief.

6.2 Implications for Theory

Theories of crisis communication suggest the importance of communicating about organizational actions and response to reduce reputational risks (Coombs et al. 2010), demonstrate transparency (Holland et al. 2021), and maintain or increase public trust (Siegrist et al. 2007). These are core goals for organizations that recognize their tenuous place in a world that is saturated with warning messages disseminated of multiple competing channels (Miller et al. 2021). In addition, researchers have found that absent public knowledge and understanding of automated warning systems such as ShakeAlert, the process and its potential points of failure must be clearly articulated to maintain trust in the system (Lee and Moray 1994; Lee and See 2004; Mehta et al. 2017; Sundar and Nass 2001; Wojton et al. 2020). When coupled with public education goals and a desire to make use of every opportunity to strengthen and increase good behavioral response (McBride et al. 2020), a message meant to gently reassure and reinforce an alerted public can miss the mark of doing either. Rather than focusing post-alert messages on providing explanations and education and reinforcing behaviors, a more effective strategy may be to immediately address elevated perceptions of risk and heightened emotions, along with the accompanying uncertainty.

Decades of empirical research on warning response (Mileti and Sorensen 1990) have led to a model that lays out the essential content necessary for initiating action in response to imminent threat (Sutton et al. 2020; Wood et al. 2018). These include information about the hazard, its impact, and the actions people should take to protect themselves (Sutton et al. 2021). Within the warning response model are echoes of what our participants asked for in a message sent following a false alert – to know whether the threat has passed (the hazard), if they are safe (the impact), and what they are advised to do next (come out from under the table).

6.3 Implications for Practice

The immediacy of a post-alert message suggests that prioritizing the informational and emotional needs of the public will serve as an appropriate communication strategy. In some cases, a post-alert message may be as important as the initial warning that motivated the protective action. Addressing concerns about what is known about safety first, followed by organizational reputation and public education second, may provide the kind of reassurance to message receivers that the hazard has been effectively managed.

6.4 Future Research

Future research should investigate alternative post-alert messages for earthquakes that take into consideration message receivers' need for reassurance of safety balanced with uncertainty about future earthquake conditions. Following an aggressive educational campaign about earthquake detection, prediction, and the place of ShakeAlert, future studies should examine public reaction to modified post-alert messages. In addition, while this study is focused on

earthquakes, it will be important to explore and confirm the effectiveness of post-alert safety message design using the Warning-Response model as the theoretical foundation across a range of events, including how to best optimize the language for different hazard contexts.

DATA AVAILABILITY

Due to privacy and ethical concerns, neither the data nor the source of the data can be made available.

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