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Testing the Effects of Increased Message Specificity for Earthquake Early Warning: Collaborative Research with the University at Albany, State University of New York, and California State University, Fullerton

Submitted by

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Table of Contents

Abstract

*Problem and Purpose***.** Understanding the best ways to craft earthquake early warning (EEW) messages to motivate people to take action is essential to realizing the potential benefits afforded by ShakeAlert and other EEW systems. ShakeAlert currently sends a single message through the Integrated Public Alert and Warning System (IPAWS), regardless of users' location or situation despite research demonstrating that personalized, detailed messages are more effective at motivating protective action than more general warnings (Frisby et al., 2014; Lindell & Perry, 2012; Sellnow et al., 2012; Sutton et al., 2018; Wood et al., 2018); however, this limitation may change in the future. The purpose of this study was to examine the potential benefit of including additional specificity in EEW messages by including information about the earthquake epicenter, countdown to shaking arrival, anticipated shaking intensity, anticipated impacts, and guidance.

*Summary of Approach***.** This one-year, collaborative project was a multi-method study incorporating quantitative and qualitative methods. Specifically, we examined the effects of: 1) including increased hazard specificity (location, time, and impact) on EEW message outcomes, 2) communicating self-protective action guidance using a bi-level approach (e.g., "protect yourself/be aware"), and 3) emphasizing different types of content (i.e., the hazard, its impacts, or protective action guidance) in the context of EEW messages. Quantitative methods consisted of six survey experiments to assess the impact of varying degrees of specificity in earthquake early warning and ShakeAlert messages. Qualitative methods consisted of six focus groups exploring the effect of "bi-level" messaging, as well as validating experimental findings.

*Results***.** Quantitative results showed that our three main hypotheses (providing greater specificity about earthquake location (epicenter), time to arrival (countdown), and consequences shaking (intensity) will lead to better message outcomes) were confirmed. Integrated results showed that participants responded appropriately to bi-level message alerting but were confused and frustrated by "be aware" messages. Although participants preferred messages with maps, messages that included maps were associated with *worse* message outcomes. While participants who viewed the message with strong shaking (MMI VI) had better message outcomes than those who viewed messages describing weak (MMI III) and moderate shaking (MMI V), they did not understand and were distracted by the Roman numerals used in communicating MMI.

*Discussion***.** The findings from this research provide immediate guidance to inform EEW messages, including ShakeAlert, as well as evidence to inform the design and implementation of future associated technologies.

Background and Introduction

This research project represents a timely, theoretically-driven and practically-relevant next step in informing the design of earthquake early warning (EEW) messages, including ShakeAlert. The project makes significant contributions to the U.S. Geological Survey (USGS) Earthquake Hazards Program (EHP) Specifically, the work addresses EEW messaging or the use of countdowns on Apps, proximity to the earthquake epicenter, and shaking intensity. It also explores potential iconography, images, and other cognitive tools that can improve understanding and use of EEW. Finally, the multi-method approach is a substantial project strength. Combining quantitative and qualitative methods allowed us to validate our findings through triangulation and better understand why people respond to EEW messages as they do.

Literature Review

The design of EEW messages delivered to mobile devices via mechanisms such as Apps and the Wireless Emergency Alert (WEA) service is a priority research area for the USGS and ShakeAlert community. These messages have the potential to alert individuals up to 90 seconds before shaking is felt, offering critical self-protection information and instruction. Importantly, the Warning Message Focus Group (WMFG) convened by the ShakeAlert JCCEO in 2017 developed a series of ShakeAlert messages for cellular devices, raising a number of questions related to their effectiveness in promoting and guiding behavioral response (Joint Committee for Communication, 2017).

By design, alert and warning messages delivered to mobile devices will be short and concise, with the goal of protective action response. Prior testing of short messages for mobile devices has focused primarily on Wireless Emergency Alerts (for a review, see Sutton & Kuligowski, 2019) and has included qualitative approaches (Bean et al., 2015, December; Bean et al., 2015) as well as online experiments (Liu et al., 2017; Sellnow & Sellnow, 2019; Wood et al., 2015, August; Wood et al., 2018) to identify individual perceptions, cognitions, and behavioral intent. Much of this work has been cross-hazard and has included a focus on near-field tsunami (Sutton et al., 2018) as well as radiological and active shooter events (Wood et al., 2015, August). Research testing the effects of alternative approaches to communicating increased specificity of earthquake location, time to impact, and consequences has not yet been conducted for EEW messages.

Empirical research shows that warning message recipients must understand, believe, personalize, and decide what to do in response to the message before taking protective action (Mileti & Sorensen, 1990; Wood et al., 2018). Furthermore, warning message recipients, regardless of hazard type, will engage in a process of collective sense-making or "milling," prior to acting (Wood et al., 2018). One goal of effective messaging is to reduce the time spent milling prior to action. This can be affected by message design choices, including the message contents and the style in which it is delivered (Mileti & Peek, 2000). Message contents that increase protective action intent include information about the threat and its potential impact, the location of impact, the timing of impact, the protective action guidance, and the source of the message sender (Frisby et al., 2014). In particular, scholars have found that *message clarity*, articulating the threat and its potential impact, and *message specificity*, identifying the location and population at risk and the time by which that population can expect to experience the threat, are both vital aspects to increase understanding, leading to both message personalization and the decision to take protective action. Other potentially important social cognitive factors include source credibility, response efficacy, self-efficacy, and affect (Bandura, 2004; Bandura, 2009; Paton, 2003).

Prior efforts have helped inform research on EEW (e.g., Nakayachi et al., 2019; Sellnow & Sellnow, 2019; Sutton et al., 2020; Wood, 2018, December 1). The present project extends prior research in an important next step in advancing the design and implementation of ShakeAlert messaging by testing the potential benefit of incorporating greater specificity about earthquake location, time to impact, and consequences in theoretically-based and practical ways, with rigorous methods and the use of sampling quotas to help reduce bias. It answers questions such as how messages might best present additional location and impact specificity to improve message response, as well as how outcomes may differ in bi-level alerting.

Currently, ShakeAlert messages are disseminated at a single level. It is possible that with the future of cell-based warning, ShakeAlert may have the ability to deliver "bi-level" messages. Bi-level messaging would provide two messages: "protect yourself" for those close to the epicenter and at higher risk of strong shaking, and "be aware" for those who are further from the epicenter and at lower risk of strong shaking. The single level message that is currently in place through ShakeAlert provides a uniform message for all audiences, directing individuals to "Drop, Cover, Hold On" to prevent injury. Bi-level messaging offers the potential to deliver messages that vary based upon a person's location and the expected intensity of shaking, directing individuals to "Protect yourself" or to "Be aware" (Joint Committee for Communication, 2017). Little is known about public perceptions of these two levels of messaging, and how they might affect response behaviors. The present research investigated the effects of increased specificity in two approaches to ShakeAlert messaging — single-level messaging, as in current practice, and bi-level messaging, as may be possible in the future and provides important insights to the design and implementation of future ShakeAlert messaging.

Study Overview

This one-year, collaborative project was a multi-method study incorporating quantitative and qualitative methods. Specifically, we examined the effects of: 1) including increased hazard specificity (location, time, and impact) on EEW message outcomes, 2) communicating self-protective action guidance using a bi-level approach (e.g., "protect yourself/be aware"), and 3) emphasizing different types of content (i.e., the hazard, its impacts, or protective action guidance) in the context of EEW messages. Quantitative methods consisted of six survey experiments to assess the impact of varying degrees of specificity in earthquake early warning and ShakeAlert messages and message ranking. Qualitative methods consisted of six focus groups exploring the effect of "bi-level" messaging and open-ended explanations of message rankings, as well as validating experimental findings.

Research Questions and Hypotheses

This study addressed one overarching research question: *What is the benefit, if any, of including additional specificity in EEW messages by including information about the earthquake epicenter, countdown to shaking arrival, and anticipated shaking intensity*. Based on the warning literature and theory, we examined the following research questions and tested the following hypotheses:

Q1: Are earthquake early warning message outcomes better when hazard location (i.e., earthquake epicenter) is communicated via text, maps, or a combination of both compared to a standard message that does not indicate hazard location?

Q2: Are earthquake early warning message outcomes better when time to impact is communicated via an analog clock or digital clock countdown compared to a standard message without a countdown?

Q3: Do earthquake early warning message outcomes vary across different lengths of time to impact?

Q4: Do people respond appropriately to bi-level earthquake early warning messages (protect yourself v. be aware)?

Q5: Do earthquake early warning message outcomes vary across different levels of shaking intensity?

Q6: Do earthquake early warning message outcomes improve when additional information about the hazard, impact, or recommended guidance are included?

H1: Providing greater specificity about the earthquake location (epicenter) will lead to better message outcomes.

H2: Providing greater specificity about the earthquake time to arrival (countdown) will lead to better message outcomes.

H3: Providing greater specificity about the earthquake consequences (intensity) will lead to better message outcomes.

Method

Methods are described for the experiments and focus groups. The research protocol (HSR-21-22-117) was approved by the California State University Fullerton Institutional Review Board (10-25-2021).

Experiments

To examine the effects of increased message specificity, we conducted six online experiments. Experiment 1 investigated message specificity in terms of earthquake location. Experiments 2-3 investigated specificity in communicating time to impact. Experiment 4 investigated message specificity in terms of earthquake consequences and bi-level messaging. Experiment 5 investigated communicating earthquake consequences in terms of differing levels of intensity. Experiment 6 compared the effect of emphasizing three different types of message content—the hazard, the impact, and the guidance. We randomly assigned participants to message conditions, and then compared message outcomes across conditions.

Experiment 1: Communicating Hazard Location

Experiment 1 examined the effect of different approaches to communicating greater specificity about the location of the earthquake epicenter. The message in the first condition was a standard ShakeAlert message (control), the message in the second condition included the number of miles the receiver was from the epicenter (standard + text), the message in the third condition included a map indicating the message receiver's location relative to the area at risk (standard + map), and the message in the fourth condition included both the number of miles from the epicenter and a map (standard + text + map).

Experiment 2: Communicating Time to Impact

Experiment 2 compared the effects of different types of earthquake countdowns. The messages tested in this experiment included the standard ShakeAlert message with no count down (Condition 1, "control"), an analog countdown, (Condition 2), and a digital countdown (Condition 3).

Experiment 3: Effect of Varied Time to Impact

Experiment 3 compared the effects of different countdown lengths. The messages tested in this experiment included the standard ShakeAlert message with no count down (Condition 1, "control"), a short 5-second countdown (Condition 2), and a long 15-second countdown (Condition 3).

Experiment 4: Effect of Bi-Level Messaging

Experiment 4 compared the effects of messages that might be included in a bi-level approach (Joint Committee for Communication, 2017) for EEW. The messages in this experiment included a message directing people to "protect yourself" (Condition 1, control) and "be aware" (Condition 2).

Experiment 5: Effect of Varied Impact

Experiment 5 compared the effects of three different levels of earthquake intensity. We added the standard ShakeAlert message (Condition 1, control) to enable comparisons with the standard ShakeAlert message. The messages tested in this experiment included messages describing "weak" Modified Mercalli Intensity (MMI) III (Condition 2), "moderate" MMI V (Condition 3), and "strong" MMI VI (Condition 4) shaking.

Experiment 6: Effect of Varied Message Focus

Experiment 6 compared the effects of emphasizing three different types of message content. We added the standard ShakeAlert message (Condition 1, control) to enable comparisons with the standard ShakeAlert message. The messages tested in this experiment included messages focused additional text on describing the hazard (Condition 2), anticipated impacts (Condition 3), and recommended guidance (Condition 4).

An overview of the experiments, including their research question, conditions tested, designated control group, and sample size, is presented in Table 1.

Table 1. *Experiment Overview*

#	IV	Question	Conditions	N
1	Location (epicenter)	Communicating hazard location	1. Standard message (control) 2. Standard and distance 3. Standard and map 4. Standard, distance, and map	489
2	Countdown (time to arrival)	Communicating time to impact	1. Standard message (control) 2. Analog countdown 3. Digital countdown	387
3	Countdown (time to arrival)	Effect of varied time to impact	1. Standard message (control) 2. Short countdown - 5 seconds 3. Long countdown - 15 seconds	384
4	Intensity (consequences)	Effect of bi-level messaging	1. "Protect yourself" message (control) 2. "Be aware" message	377
5	Intensity (consequences)	Effect of varied impact	1. Standard message (control)* 2. "Weak" shaking - MMI III 3. "Moderate" shaking - MMI V 4. "Strong" shaking - MMI VI	380
6	Message emphasis	Effect of varied message focus	1. Standard message (control)* 2. Focus on hazard 3. Focus on impact (strong MMI 6) 4. Focus on guidance (DCHO)	384
Dependent variables: Message Understanding, Belief, Personalization, Deciding, Milling, Source Credibility, Response Efficacy, Self-Efficacy, and Affect **Note*: The Standard message control group for Experiment 1 was also used in Experiments 5 and 6 (*n*=121) to enable comparisons.				**2,401**

Experiments: Stimuli

Stimuli for the experiments and focus groups were developed by the research team, reviewed by the USGS Social Science Working Group (SSWG), and revised based on feedback. Colors were selected in accordance with Web Content Accessibility Guidelines (WCAG) to increase accessibility by meeting a 4.5:1 contrast ratio between foreground and background colors (The World Wide Web Consortium - W3C, 2008). Experiment stimuli are included in Figures 1 - 6.

Figure 1. *Experiment 1 Stimuli: Communicating Hazard Location*

Condition 1
Standard message, Control

Condition 2
Standard + distance

Condition 3
Standard + map

Condition 4
Standard + distance + map

Figure 2. *Experiment 2 Stimuli: Communicating Time to Impact*

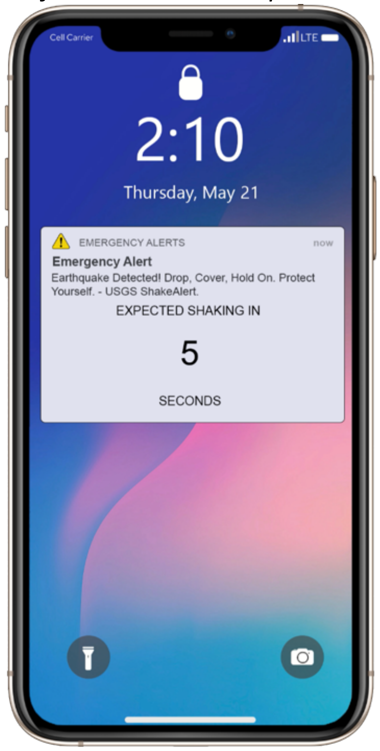
Condition 1
Standard message, Control

Condition 2
Analog countdown

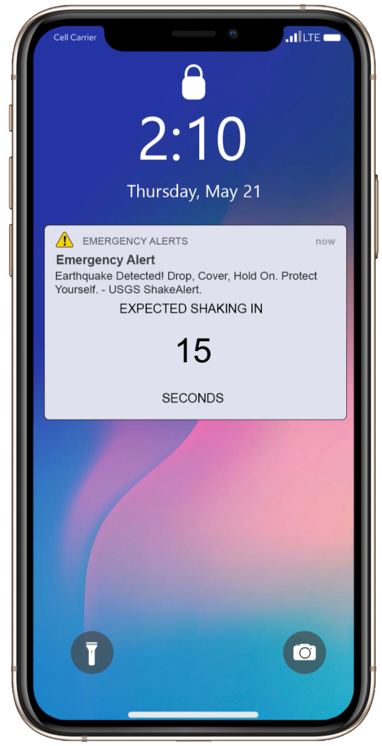
Condition 3
Digital countdown

Figure 3. *Experiment 3 Stimuli: Effect of Varied Time to Impact*

Condition 1
Standard message, Control

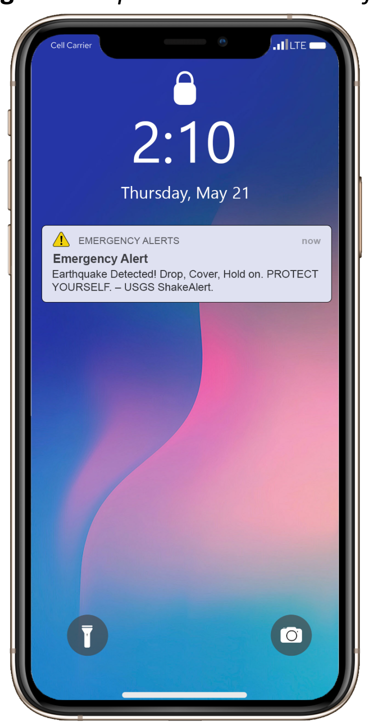


Condition 2
Short countdown (5 sec.)



Condition 3
Long countdown (15 sec.)

Figure 4. *Experiment 4 Stimuli: Effect of Bi-Level Messaging*



Condition 1
"Protect yourself", Control

Condition 2
"Be aware"

Figure 5. *Experiment 5 Stimuli: Effect of Varied Impact*

Condition 1	Condition 2	Condition 3	Condition 4
Standard message, Control	*"Weak" (MMI III)*	*"Moderate" (MMI V)*	*"Strong" (MMI VI)*

Figure 6. *Experiment 6 Stimuli: Effect of Focus on Hazard, Impact, Guidance*

Condition 1	Condition 2	Condition 3	Condition 4
Standard message, Control	*Standard + hazard*	*Standard + impact*	*Standard + guidance*

Experiments: Procedure

Sampling. Experiment participants were recruited via Qualtrics online panels. Online panelists are acquired using various sources, including targeted email lists, member referrals, customer loyalty website portals, permission-based networks, gaming sites, website intercept recruitment, and social media. Afterward, panel members' names, addresses, and birthdates are validated using third-party verification measures before joining a panel. For each study, panel members are then either sent an invitation email or text message or are prompted on the survey platform to complete a study for which they are eligible. The invitation (whether by email, text message, or platform display) is typically straightforward, informs the participant of the incentive, and contains a hyperlink to the survey.

Qualtrics online panelists receive approximately 70% of the per survey cost. They are not provided direct cash payments but are instead given points equivalent to monetary value. The approach functions similar to a credit card rewards program, in which the panelist collects points to use toward gifts, travel, and other products.

For this study, potential participants were required to be at least 18 years of age and live on the west coast of the United States (in the states of California, Oregon, or Washington). An attempt was made to evenly distribute the proportion of participants from each state according to population: aiming for 77% in California, 15% in Washington, and 8% in Oregon. Each individual's residency in one of those states was confirmed using the home zip code provided at the start of the survey. Participants whose entered zip codes did not match with one of the 2,744 zip codes within the three states were marked as ineligible and excluded from the survey.

From the start of the study, individuals were intended to participate in only one of the six experiment surveys, meaning they should not participate in multiple experiment surveys. However, throughout the merging of all experiment datasets, open-ended data gave the impression of some cases of the same individual completing more than one experiment survey. Review of experiment group values and IP address of the participant confirmed this hunch. These individuals were cleared from the collected dataset and replaced with new participants who had not yet completed one of the six experiment surveys.

Sample sizes were determined based on power analyses conducted using G*Power software assuming small-to-medium effect sizes (f=.175), Power=.80, and alpha=.05, based on the number of conditions tested in each experiment.

Table 2 displays the response rates for each of the experiment groups as well as the total. The response rate for the online panels is calculated by dividing the number of participants who complete a survey by the number of eligible individuals invited to complete the survey. As shown, the overall response rate for the experiment surveys combined was 18% (2,401 completed surveys/13,345 invite links sent.)

Questionnaire Design and Pretesting. The survey questionnaire was developed by the research team and was guided by our theoretical framework. The experiment used a "between-subjects" design in that each participant was randomized to one of the message conditions. The independent variable was message condition. Dependent variables (outcomes) included key warning response variables (understanding, belief, personalization, milling, and deciding) and social cognitive variables (source credibility, response efficacy, self-efficacy, and affect). Pre-existing tested scales were used when possible. Most items were measured on a 1-5 Likert-type scale ranging from "Strongly Disagree" to "Strongly Agree"; Affect was measured on a 7-point semantic differential scale. Milling (response delay) was scored as an index: those who reported they would immediately take protective action scored a 1 (low delay), those who reported they would check on others or wait to feel shaking before taking action scored a 2, those who reported they would wait for both scored a 3, and those who reported they would ignore the message and not take action scored a 4. Outcome measures are included in Appendix I.

Table 2. *Experiment Response Rates*

	Experiment #						
	1	2	3	4	5	6	Total
Invites Sent	2,371	2,502	2,186	2,034	2,239	2,013	13,345
Invite Links Clicked	1,549	1,856	1,639	1,425	1,578	1,620	9,667
Completed Surveys	489	387	384	377	380	384	2,401
Response Rate	21%	16%	18%	18%	17%	19%	18.0%

Data Collection. The experiments were conducted using Qualtrics online survey software. Recruited participants were residents of three states with elevated earthquake risk (California, Oregon, and Washington). In addition, participants were required to speak English and be at least 18 years of age to be eligible. The questionnaire took roughly 15 and a half minutes to complete (M=15.5, SD=11.4). Experiment findings were compared to focus group findings to increase validity and provide more complete understanding.

Participants were randomly assigned to a condition by the Qualtrics survey software, presented with their randomly assigned EEW message, and then answered items measuring the outcome variables. After this, they were presented with the complete set of messages tested in the experiment (i.e., a total of 2-4 messages) and were asked to rank order them based on their perceived ability to motivate protective action. We also asked participants to explain their rationale for their rank ordering in an open-ended item.

Data Analysis. Data were cleaned and reviewed for plausibility; those that showed signs of faulty open-ended responses (i.e., those with random letters, numbers, or words rather than answers to the item) were eliminated. The open-ended answers were scanned for spelling and grammar issues and were cleaned. Open-ended items allowing participants to specify their response of "other" were reviewed to ensure they were true answers to the question at hand. For those text answers that were non-responsive, the associated closed-ended responses were deleted. Additionally, the open-ended responses themselves were deleted if they appeared to indicate the participant did not wish to answer the question (e.g., "N/A," "no comment," or "nothing") unless the response was itself meaningful.

Scales were created; and internal consistency was calculated using Cronbach's alpha (see Table 3). One-way Analysis of Variance (ANOVA) was performed for each experiment separately; all statistical assumptions for ANOVA were met. SPSS was used to conduct the statistical analysis. We interpreted statistical significance along the conventional $p < .001$, $p < .01$, $p < .05$ thresholds. Following logic from Tshikuka and colleagues (2016), we also note results indicating "borderline significance" where $p < .10$. We interpret magnitudes for effect sizes (partial eta-squared) as .01 = "small", .06 = "medium", and .14 = "large", using thresholds offered by Cohen (1988). In a public messaging context, small effect sizes can have large impacts when spread over populations and may translate to reduced injury, mortality, and costs.

Experiments: Sample Characteristics

Experiment sample characteristics are presented in Table 4.

Table 3. *Internal Consistency of Outcome Scales (Cronbach's α)*

	Experiment #					
Variable	1	2	3	4	5	6
Understanding	.84	.84	.85	.86	.85	.85
Belief	.86	.88	.89	.88	.87	.88
Personalization	.92	.92	.94	.94	.93	.92
Deciding	.92	.89	.92	.93	.91	.92
Source Credibility	.96	.96	.96	.97	.96	.96
Response efficacy	.73	.73	.78	.76	.76	.76
Self-Efficacy	.90	.91	.92	.94	.89	.90
Response Costs	.84	.83	.84	.82	.83	.84
Affect	.88	.86	.89	.87	.88	.89

Note: Milling is excluded because inter-item consistency was not relevant for this construct.

Table 4. *Experiment Sample Characteristics*

	Experiment #													
	1		2		3		4		5		6		Total	
	N=489		*N*=387		*N*=384		*N*=377		*N*=380		*N*=384		*N*=2,401	
Characteristic	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%	*n*	%
Sex														
Male	193	40	168	43	162	42	177	47	173	46	158	41	1,031	43
Female	291	59	212	55	214	56	191	51	202	53	221	58	1,331	55
Other	4	1	5	1	6	2	9	2	4	1	5	1	33	2
Decline	1	<1	2	1	2	<1	0	0	1	<1	0	0	6	<1
Hispanic, Latino														
Yes	70	14	59	15	63	16	58	15	77	20	86	22	413	17
No	419	86	328	85	321	84	319	85	303	80	298	78	1,988	83
Race/Ethnicity														
African American	28	6	32	8	40	10	19	5	25	7	32	8	176	7
Am Ind/Alask. Native	17	4	12	3	8	2	11	3	13	3	11	3	72	3
Middle Eastern	0	0	0	0	3	1	7	2	3	1	3	1	16	1
Pacific Islander	6	1	5	1	5	1	10	3	6	2	5	1	37	2
East Asian	22	5	18	5	23	6	14	4	22	6	25	7	124	5
South Asian	11	2	5	1	9	2	4	1	7	2	8	2	44	2
Southeast Asian	11	2	9	2	5	1	7	2	6	2	14	4	52	2
White	345	71	282	73	244	64	278	74	243	64	236	62	1628	68
Other	7	1	6	2	8	2	5	1	7	2	3	1	36	2
Age														
18-29 years	105	22	66	17	110	29	69	18	99	26	109	28	558	23
30-49 years	149	31	132	34	122	32	131	35	146	38	169	44	849	35
50-69 years	136	28	114	30	93	24	106	28	87	23	65	17	601	25
70+ years	99	20	75	19	59	15	71	19	48	13	41	11	393	16

Focus Groups

The purpose of the focus groups was to explore responses to 1) bi-Level earthquake early warnings and 2) warning elements that increase message specificity about impact, location, and time.

In 2017, the Warning Message Focus Group (WMFG) of the ShakeAlert Joint Committee for Communication, Education, and Outreach (JCCEO) produced a report with recommendations for rolling out ShakeAlert earthquake early warning (EEW) messages for public alerts via mobile devices. Importantly, the Alliance for Telecommunications Industry Solutions (ATIS) explained that the intended roll out of the standard EEW message was an ambitious delivery deadline (p.4) and that “cell technology will not – now, or in the near future – be able to provide tailoring of the message based on the recipient’s location (level of shaking expected; time to shaking arrival; expected duration)” (p. 4). Subsequently, The JCCEO WMFG “began its deliberations supporting a bi-level message” (p. 5). Bi-level messaging would consist of the following:

> *At lower levels of shaking, a “be aware” message would familiarize the public with the cell-based ShakeAlert (early warning message), and at higher levels of shaking, a “take action” message. This bi-level approach was also identified by the WMFG as important to promote public understanding of the situation and acceptance of the ShakeAlert system during active aftershock sequences.*

While the standard, single-level message has been implemented in ShakeAlert messages, there remain questions about bi-level EEW messages. In particular, there is interest in exploring public responses to bi-level EEW under varying conditions, such as messages sent after the public have experienced a “real” alert, a false alert, or a missed alert, and how those experiences may affect message understanding, believing, personalizing, deciding, information seeking, and behavioral intent.

Even with the absence of bi-level alerting sent via cell technology, this question about public perceptions and behavioral intent remains important because there are already warning systems integrated into existing platforms/providers/technology that DO employ bi-level alerting.

Earthquake researchers express hesitancy about the implementation of the bi-level alerting for multiple reasons, including changes in the calculation of the distance/magnitude while the models are performing calculations, and concerns that the initial calculations will result in incorrectly identifying who should take action and who should be aware. The potential for updated modeling as the earthquake is occurring leads to concerns that incorrect messaging, such as a “protect yourself” message sent to individuals who do not experience significant shaking, may result in message receivers being less inclined to act in future warning events (fear of over-warning), or when a “be aware” message is sent but individuals experience significant shaking and were not told to take action. Notably, this second condition might also result in persons being harmed without adequate warning.

In light of these concerns, this research used focus groups to investigate how EEW message receivers might respond to the two types of messages (protect yourself, be aware). In particular, we were interested in perceptions of, and behavioral intent in response to, the “Drop, Cover, Hold On” (DCHO) recommendations in a “be aware” message when no shaking is expected.

Focus Groups: Discussion Guide and Topics

Six focus groups were conducted with approximately eight persons per group. Three focus groups received a "protect yourself" message followed by one of three conditions: no shaking, minimal shaking, strong shaking; the other three focus groups received a "be aware" message followed by one of the three conditions: no shaking, minimal shaking, strong shaking.

Each focus group also provided feedback on messages designed to increase specificity (see stimuli below). Messages that included increased specificity in terms of time, impact, and location were viewed by two groups, each (total number of groups = 6).

Table 5. *Focus Group Discussion Topics*

	Message Type		**Shaking Intensity**			**Additional Stimuli Type**		
Group #	Protect Yourself	Be Aware	No Shaking	Minimal Shaking	Strong Shaking	Stim 1 *Time*	Stim 2 *Impact*	Stim 3 *Location*
1	X		X			X		
2	X			X			X	
3	X				X			X
4		X	X				X	
5		X		X		X		
6		X			X			X

Focus Groups: Stimuli

The two messages are drawn from the JCCEO-WMFG message design recommendations for "protect yourself" and "be aware" messages, with feedback from the SSWG and program directors (McBride and DeGroot). Colors were chosen in accordance with Web Content Accessibility Guidelines (WCAG) to increase message accessibility by meeting a 4.5:1 contrast ratio between foreground and background colors (The World Wide Web Consortium - W3C, 2008). Focus group stimuli are presented in Figures 7 – 10.

Protect Yourself. The text of the "protect yourself" message for higher-level shaking was:

"Earthquake Detected! Drop, Cover, Hold On. Protect yourself. - USGS ShakeAlert."

Be Aware. The text of the "be aware" message for lower-level shaking was:

"Earthquake Detected! Shaking may occur. Drop, Cover, Hold on. Be aware. – USGS ShakeAlert."

Figure 7. *Stimuli Presented to all Focus Groups*

Figure 8. *Stimuli Presented to Focus Groups 1 and 4*

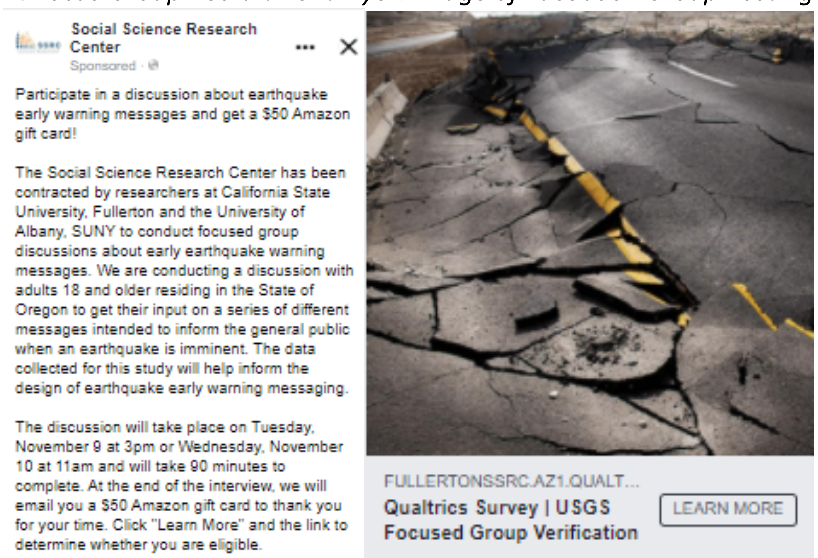
Figure 9. *Stimuli Presented to Focus Groups 2 and 5*

Figure 10. *Stimuli Presented to Focus Groups 3 and 6*

Focus Groups: Procedure

Recruitment. Participants were recruited to participate in focus group discussions using an advertisement distributed on Facebook to individuals in the states of California, Oregon, and Washington who were believed to be at least 18 years of age. The advertisement (below) included an image of a road severely damaged by a serious earthquake. Individual advertisements were made separately for each state. However, the advertisements remained identical, with the exception of the state named and dates available for discussions. The number of days each advertisement was published varied from a few days to about a week, depending on the state in which it was being advertised. The advertisement explained that residents within the corresponding state over the age of 18 years old were eligible to participate in a discussion about early earthquake warning messages. A $50 Amazon gift card was offered as an incentive to participate. A button, containing the phrase "learn more," was provided at the bottom of the advertisement and linked to an eligibility screening survey.

Figure 11. *Focus Group Recruitment Flyer: Image of Facebook Group Posting*



The screening survey informed potential recruits that they would be asked to determine whether they were eligible to participate in an online focus group. Recruits were then asked to verify their state, selected which date/time they might be able to participate, confirmed they had a computer with reliable internet and audio, and indicated they would be willing to download Zoom to their device. They were also asked to confirm they were 18 years of age or older. Those found to be eligible were then asked to provide their name, telephone, and up to two email addresses to contact them.

Individuals who completed the survey and were found to be eligible were first contacted via email to confirm they were indeed available to participate in an online focus group discussion and to respond with the word "RSVP." This email reiterated the eligibility criteria administered in the screening survey as well as provided information on how to download Zoom and access the meeting. As necessary, particularly when the number of registrants who confirmed they would attend via email was low, telephone calls were also made as an alternate method of confirming attendance. Outreach to registrants continued until at least ten confirmed their availability for each group (in anticipation that some registrants who confirmed their availability would not show up). A final email was sent either the night prior to or morning of the focus group discussion, providing the same information and link as the initial email. Between nine and fourteen individuals stated (by either email or phone) they would attend each discussion. Ultimately, each consisted of between five and thirteen participants.

Focus groups were conducted by a moderator and notes were taken by the focus group assistants throughout each session. To begin, focus group participants were welcomed to the Zoom session and gave verbal consent to being audio recorded. After that, the recording was turned on and participants introduced themselves by describing their experience with earthquakes.

Process. The focus group protocol was divided into four parts. In part one, a scenario was introduced where participants were told it was afternoon and they received a message on their cell phone. Participants were then shown one of the two messages (protect yourself or be aware), followed by discussion about the message. They were informed about the level of shaking they felt after receiving the message (no shaking, minimal shaking, or strong shaking) and were asked to discuss how this affected their initial reaction to the message. In part two, participants were shown a series of messages that were designed to increase specificity about time, impact, or location. After viewing each message one at a time they were asked to provide their initial feedback. Then, each of the messages in the series were seen, side-by-side, and participants were asked to discuss them in comparison and rank them in order of most to least preferred. In part three, participants were introduced to a new scenario, where they receive the same message that was delivered in the first scenario, but six months later. They were asked to discuss their reaction and intended response to the message premised on their prior alerting experience. In part four, the focus group moderator explained the premise for sending each of the two message types – protect yourself and be aware. Participants were then shown both messages and asked to discuss them in comparison to each other. Focus groups concluded with a wrap up and a link to the ShakeAlert website for further information.

Analysis. Each focus group recording was automatically transcribed (via Zoom) and checked for accuracy. Notes from group assistants were referenced to highlight consistent and divergent perspectives from focus group participants. These notes were helpful in identifying the emergent themes from transcripts. Transcripts were coded for thematic responses to each question.

Focus Groups: Sample Characteristics

Focus group participant characteristics are presented in Table 6.

Table 6. *Focus Group Sample Characteristics (N=52)*

Characteristic	*n*	%
Sex		
Male	20	38.4
Female	36	69.2
Hispanic or Latino Origin		
Yes	2	3.8
No	50	96.4
Age		
18-29 years	5	9.6
30-49 years	9	17.3
50-65 years	17	32.6
76+ years	9	17.3
Prefer not to say	16	30.7

Results

Experiments

Experiment univariate statistics for warning response outcomes (understanding, belief, personalization, deciding, and milling) are presented in Table 7, and social cognitive outcomes (source credibility, response efficacy, self-efficacy, and affect) are presented in Table 8. Detailed descriptions of ANOVA results for the six experiments follow. See Appendix II for bar (mean) plots and significance levels for pairwise comparisons.

Table 7. *Univariate Statistics: Warning Response Outcomes*

Experiment			Understanding		Belief		Personalization		Deciding		Milling	
#	Condition	*N*	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)	Mean	(SD)
1	Standard (Control)	121	3.79	(.85)	4.09	(.85)	3.70	(.97)	3.66	(1.13)	1.41	(.54)
	Standard + Text	113	4.04	(.79)	4.14	(.82)	3.80	(.89)	4.04	(1.00)	1.43	(.71)
	Standard + Map	142	3.81	(.82)	4.07	(.81)	3.58	(.97)	3.85	(1.01)	1.48	(.64)
	Standard + Text + Map	113	3.96	(.75)	4.06	(.82)	3.48	(.91)	3.79	(1.01)	1.42	(.64)
	Total	489	3.89	(.81)	4.09	(.82)	3.64	(.94)	3.83	(1.04)	1.44	(.63)
2	Standard (Control)	137	3.73	(.93)	3.93	(.95)	3.52	(.99)	3.84	(1.10)	1.50	(.65)
	Analog Countdown	124	3.69	(.86)	4.03	(.89)	3.54	(.91)	3.85	(1.01)	1.52	(.77)
	Digital Countdown	126	3.69	(.84)	4.15	(.76)	3.60	(.90)	3.78	(.94)	1.44	(.64)
	Total	387	3.70	(.88)	4.04	(.87)	3.55	(.93)	3.82	(1.02)	1.49	(.69)
3	No Countdown (Control)	119	3.70	(.89)	3.94	(.83)	3.58	(1.04)	3.93	(.98)	1.50	(.64)
	Short Countdown (5 sec)	145	3.71	(.77)	4.04	(.81)	3.52	(.92)	3.76	(1.08)	1.44	(.67)
	Long Countdown (15 sec)	120	3.85	(.95)	4.22	(.90)	3.68	(1.09)	3.97	(1.13)	1.46	(.73)
	Total	384	3.75	(.87)	4.06	(.85)	3.59	(1.01)	3.88	(1.07)	1.47	(.68)
4	Protect Yourself (Control)	193	3.77	(.91)	4.00	(.86)	3.52	(1.05)	3.87	(1.05)	1.49	(.76)
	Be Aware	184	3.52	(.92)	3.80	(.94)	3.35	(.98)	3.64	(1.11)	1.50	(.68)
	Total	377	3.65	(.92)	3.90	(.90)	3.44	(1.02)	3.76	(1.08)	1.50	(.72)
5	Standard (Control)	121	3.79	(.85)	4.09	(.85)	3.70	(.97)	3.66	(1.13)	1.41	(.54)
	Weak (MMI III)	116	3.57	(.97)	3.77	(.90)	3.20	(1.07)	3.89	(1.01)	1.62	(.67)
	Moderate (MMI V)	122	3.56	(.88)	3.75	(.91)	3.27	(1.08)	3.70	(1.02)	1.56	(.62)
	Strong (MMI VI)	142	3.80	(.77)	4.08	(.79)	3.80	(.83)	3.76	(1.06)	1.44	(.56)
	Total	501	3.68	(.87)	3.93	(.87)	3.51	(1.02)	3.75	(1.05)	1.50	(.60)
6	Standard (Control)	121	3.79	(.85)	4.09	(.85)	3.70	(.97)	3.66	(1.13)	1.41	(.54)
	Hazard Focus	122	3.77	(.78)	4.02	(.84)	3.66	(.89)	3.78	(.98)	1.52	(.65)
	Impact Focus	131	3.76	(.80)	4.02	(.82)	3.61	(.87)	3.87	(.95)	1.47	(.54)
	Guidance Focus	131	3.73	(.90)	3.93	(.92)	3.51	(.96)	3.93	(.95)	1.40	(.57)
	Total	505	3.76	(.83)	4.01	(.86)	3.62	(.92)	3.81	(1.00)	1.45	(.58)

Note: Means are unadjusted.

Table 8. *Univariate Statistics: Social Cognitive Outcomes*

#	Experiment Condition	*N*	Source Credibility Mean	(SD)	Response Efficacy Mean	(SD)	Self-Efficacy Mean	(SD)	Affect Mean	(SD)
1	Standard (Control)	121	4.09	(.89)	3.73	(.93)	3.91	(1.01)	3.64	(1.69)
	Standard + Text	113	4.23	(.89)	3.98	(.83)	4.14	(.89)	3.93	(1.65)
	Standard + Map	142	4.14	(.87)	3.83	(.75)	3.96	(.91)	3.58	(1.64)
	Standard + Text + Map	113	4.06	(.86)	3.82	(.80)	3.92	(.91)	3.36	(1.30)
	Total	489	4.13	(.88)	3.84	(.83)	3.98	(.93)	3.62	(1.59)
2	Standard (Control)	137	3.99	(1.02)	3.73	(.88)	4.01	(.99)	3.34	(1.52)
	Analog Countdown	124	3.97	(.88)	3.77	(.83)	3.95	(.98)	3.95	(1.65)
	Digital Countdown	126	4.06	(.93)	3.71	(.82)	3.98	(.85)	3.52	(1.46)
	Total	387	4.01	(.94)	3.74	(.84)	3.98	(.94)	3.59	(1.56)
3	No Countdown (Control)	119	4.00	(.98)	3.73	(.89)	3.96	(.99)	3.66	(1.62)
	Short Countdown (5 sec)	145	4.02	(.85)	3.81	(.89)	3.93	(.97)	3.77	(1.60)
	Long Countdown (15 sec)	120	4.22	(.94)	3.81	(.99)	3.95	(1.10)	3.59	(1.58)
	Total	384	4.08	(.92)	3.78	(.92)	3.94	(1.01)	3.68	(1.60)
4	Protect Yourself (Control)	193	4.05	(.94)	3.75	(.89)	4.01	(.96)	3.46	(1.53)
	Be Aware	184	3.83	(1.12)	3.59	(.92)	3.81	(1.07)	3.53	(1.45)
	Total	377	3.94	(1.03)	3.67	(.91)	3.92	(1.02)	3.50	(1.49)
5	Standard (Control)	121	4.09	(.89)	3.73	(.93)	3.91	(1.01)	3.64	(1.69)
	Weak (MMI III)	116	3.92	(.98)	3.77	(.87)	3.95	(.98)	3.75	(1.52)
	Moderate (MMI V)	122	3.79	(1.08)	3.67	(.93)	3.83	(.98)	3.64	(1.41)
	Strong (MMI VI)	142	4.08	(.78)	3.82	(.80)	3.94	(.85)	3.81	(1.67)
	Total	380	3.97	(.94)	3.75	(.88)	3.91	(.95)	3.71	(1.58)
6	Standard (Control)	121	4.09	(.89)	3.73	(.93)	3.91	(1.01)	3.64	(1.69)
	Hazard Focus	122	4.09	(.92)	3.75	(.85)	3.86	(.93)	3.75	(1.65)
	Impact Focus	131	4.09	(.84)	3.89	(.79)	4.06	(.87)	3.75	(1.60)
	Guidance Focus	131	3.98	(.94)	3.92	(.81)	3.93	(.96)	3.72	(1.59)
	Total	505	4.06	(.90)	3.83	(.85)	3.94	(.94)	3.72	(1.62)

Note: Means are unadjusted.

Experiment 1

Experiment 1 compared four different message stimuli each representing different ways of communicating hazard location. ANOVA results indicated significant differences by condition in understanding (F(3, 485)=2.669, p=.047) and deciding (F(3, 485)=2.778 p=.041), with results approaching significance for personalization (F(3, 485)=2.467, p=.061) and affect (F(3, 485)=2.449, p=.063). See Table 9.

There were no significant differences in believing, milling, source credibility, response efficacy, or self-efficacy.

Table 9. *Experiment 1: ANOVA Results for Communicating Hazard Location*

Outcome	Type III Sum of Squares	Mean Square	*F* *(DF=3)*	Sig.	Partial Eta Squared
Understanding	5.170	1.723	2.669	**.047***	.016
Belief	.460	.153	.226	.878	.001
Personalization	6.545	2.182	2.467	**.061**†	.015
Deciding	8.955	2.985	2.778	**.041***	.017
Milling	.369	.123	.307	.820	.002
Source Credibility	1.920	.640	.832	.477	.005
Response Efficacy	3.641	1.214	1.771	.152	.011
Self-Efficacy	3.788	1.263	1.457	.225	.009
Affect	18.412	6.137	2.449	**.063**†	.015

Understanding. Respondents who received the standard ShakeAlert message plus additional text indicating their proximity to the epicenter (Condition 2) showed significantly greater levels of message understanding (*M*=4.04, *SE*=.076) compared to those who received the Standard message (Condition 1) (*M*=3.79, *SE*=.073; *p*=.02) and the standard message plus a map showing their distance from the epicenter visually (Condition 3) (*M*=3.82, *SE*=.067; *p*=.03). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.016).

Deciding. Respondents who received the standard ShakeAlert message plus additional text (Condition 2) showed significantly greater levels of deciding (*M*=4.04, *SE*=.098) compared to those who received the Standard message (Condition 1) *M*=3.66, *SE*=.094; *p*=.005) and the Standard message plus additional text and a map (Condition 4) (*M*=3.79, *SE*=.098; *p*=.07, approaching significance). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.017).

Personalization. Respondents who received the standard ShakeAlert message plus additional text (Condition 2) showed significantly greater levels of personalization (*M*=3.80, *SE*=.088) compared to those who received the Standard message plus additional text and a map (Condition 4) (*M*=3.48, *SE*=.088; *p*=.01) and the Standard message plus a map (Condition 3) (*M*=3.58, *SE*=.079; *p*=.08, approaching significance). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.015).

Affect. Respondents who received the standard ShakeAlert message plus additional text (Condition 2) showed significantly greater levels of positive affect (*M*=3.93, *SE*=.149) compared to those who received the Standard message plus additional text and a map (Condition 4) (*M*=3.36, *SE*=.149; *p*=.008) and the Standard message plus a map (Condition 3) (*M*=3.58, *SE*=.133; *p*=.08, approaching significance). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.015).

Message Preferences. After the outcome scale items were completed, we presented participants with all stimuli and asked them to rank order the messages based on how well they thought the messages would motivate protective action (*N*=489). Most respondents ranked Condition 4, the Standard message plus additional text and a map highest (*n*=279, 57%), followed by Condition 2, the Standard message plus additional text (*n*=108, 22%), Condition 1, the Standard message (*n*=55, 11%), and Condition 3, the Standard message plus a map (*n*=47, 9%).

Summary. In the very immediate time-to-impact earthquake context, the standard ShakeAlert message plus additional text describing the distance from the earthquake epicenter or hazard location was associated with better outcomes than the other messages; messages that contained maps had worse outcomes.

Experiment 2

Experiment 2 compared three different stimuli communicating time to impact. ANOVA results indicated significant differences by condition in affect, $F(2, 384)=25.467$, $p=.005$. See Table 10.

There were no significant differences found in understanding, belief, personalizing, deciding, milling, source credibility, response efficacy, or self-efficacy.

Table 10. *Experiment 2: ANOVA Results for Communicating Time to Impact*

Outcome	Type III Sum of Squares	Mean Square	*F* *(DF=2)*	Sig.	Partial Eta Squared
Understanding	.120	.060	.078	.925	.000
Belief	3.215	1.607	2.121	.121	.011
Personalization	.505	.253	.289	.749	.002
Deciding	.420	.210	.202	.817	.001
Milling	.464	.232	.489	.614	.003
Source Credibility	.500	.250	.279	.756	.001
Response Efficacy	.273	.136	.191	.826	.001
Self-Efficacy	.262	.131	.148	.862	.001
Affect	25.467	12.733	5.362	**.005***	.027

Affect. Respondents who received the analog countdown message (Condition 2) showed significantly higher levels of positive affect ($M=3.95$, $SE=.138$) compared to those who received the standard ShakeAlert message (Condition 1) with no countdown ($M=3.34$, $SE=.132$; $p<.001$) and the digital countdown (Message Condition 3) ($M=3.52$, $SE=.137$; $p=.026$). According to Cohen (1988), the overall effect size for this outcome is considered “small” (Partial $\eta 2=.027$).

Message Preferences. When we presented participants with all stimuli and asked them to rank order the messages based on how well they believed the messages would motivate protective action, most ranked ($N=387$) Condition 3, the Standard message plus a digital countdown, highest ($n=165$, 43%), followed by Condition 2, the Standard message plus an analog countdown ($n=125$, 32%), and Condition 1, the Standard message with no countdown ($n=97$, 25%).

Summary. The message showing the analog countdown was associated with higher levels of affect (i.e., more positive) than the other messages, though the message included in Condition 3, the digital countdown, was rated highest by participants.

Experiment 3

Experiment 3 compared three different stimuli communicating different lengths of time to hazard impact. ANOVA results indicated significant differences by condition in belief, $F(2, 381)=3.314$, $p=.037$. See Table 11.

There were no significant differences found in understanding, personalizing, deciding, milling, source credibility, response efficacy, self-efficacy, or affect.

Table 11. *Experiment 3: ANOVA Results for Time to Impact*

Outcome	Type III Sum of Squares	Mean Square	*F* *(DF=2)*	Sig.	Partial Eta Squared
Understanding	1.656	.828	1.100	.334	.006
Belief	4.747	2.373	3.314	**.037***	.017
Personalization	1.505	.753	.731	.482	.004
Deciding	3.367	1.683	1.483	.228	.008
Milling	.269	.134	.292	.747	.002
Source Credibility	3.655	1.828	2.174	.115	.011
Response Efficacy	.481	.240	.281	.755	.001
Self-Efficacy	.053	.026	.026	.975	.000
Affect	2.292	1.146	.447	.640	.002

Belief. Respondents who received the long time to impact countdown (Condition 3) showed significantly greater levels of message belief (*M*=4.22, *SE*=.077) compared to those who received the standard message (Condition 1) with no countdown (*M*=3.94, *SE*=.078; *p*=.012) and the short countdown (Condition 2) (*M*=4.04, *SE*=.070; *p*=.086, approaching significance). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η^2=.017).

Message Preferences. When we presented participants with all stimuli and asked them to rank order the messages based on how well they believed the messages would motivate protective action, most ranked (*N*=377) Condition 3, the long countdown highest (*n*=215, 56%), followed by Condition 2, the short countdown (*n*=89, 23%), and Condition 1, the Standard message with no countdown (*n*=80, 21%).

Summary. The message that contained the long countdown (Condition 3) was associated with better message outcomes than the other messages, and a majority viewed the long countdown as most effective.

Experiment 4

Experiment 4 compared two different stimuli communicating earthquake intensity using a "protect yourself" message for higher earthquake shaking intensity (Condition 1) and a "be aware" message for lower shaking intensity (Condition 2). ANOVA results indicated significant differences by condition in message understanding (*F*(1, 375)=7.090, *p*=.008), belief (*F*(1, 375)=4.557, *p*=.033), deciding (*F*(1, 375)=4.372, *p*=.037), source credibility (*F*(1, 375)=4.006, *p*=.046), and differences approaching statistical significance for response efficacy (*F*(1, 375)=2.909, *p*=.089) and self-efficacy (*F*(1, 375)=3.627, *p*=.058). See Table 12.

There were no significant differences found in personalization, milling, or affect.

Table 12. *Experiment 4: ANOVA Results for "Bi-Level" Messaging*

Outcome	Type III Sum of Squares	Mean Square	*F* *(DF=1)*	Sig.	Partial Eta Squared
Understanding	5.899	5.899	7.090	**.008***	.019
Belief	3.686	3.686	4.557	**.033***	.012
Personalization	2.731	2.731	2.656	.104	.007
Deciding	5.097	5.097	4.372	**.037***	.012
Milling	.006	.006	.011	.917	.000
Source Credibility	4.251	4.251	4.006	**.046***	.011
Response Efficacy	2.386	2.386	2.909	**.089**†	.008
Self-Efficacy	3.718	3.718	3.627	**.058**†	.010
Affect	.440	.440	.197	.658	.001

Understanding. Respondents who received the "protect yourself" message (Condition 1) showed significantly greater levels of message understanding (*M*=3.77, *SE*=.066) compared to those who received the "be aware" message (Condition 2) (*M*=3.52, *SE*=.067; *p*=.008). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.019).

Belief. Respondents who received the "protect yourself" message (Condition 1) showed significantly greater levels of belief (*M*=4.00, *SE*=.065) compared to those who received the "be aware" message (Condition 2) (*M*=3.80, *SE*=.066; *p*=.033). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.012).

Deciding. Respondents who received the "protect yourself" message (Condition 1) reported significantly greater levels of deciding (*M*=3.87, *SE*=.078) compared to those who received the "be aware" message (Condition 2) (*M*=3.64, *SE*=.080; *p*=.037). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.012).

Source Credibility. Respondents who received the "protect yourself" message (Condition 1) reported significantly greater levels of source credibility (*M*=4.05, *SE*=.074) compared to those who received the "be aware" message (Condition 2) (*M*=3.83, *SE*=.076; *p*=.046). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.011).

Response Efficacy. Respondents who received the "protect yourself" message (Condition 1) showed greater levels of response efficacy (*M*=3.22, *SE*=.049, approaching significance) compared to those who received the "be aware" (Condition 2) (*M*=3.10, *SE*=.050; *p*=.089). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.008).

Self-Efficacy. Respondents who received the "protect yourself" message (Condition 1) showed greater levels of self-efficacy (*M*=4.01, *SE*=.073) compared to those who received the "be aware" message (Condition 2) (*M*=3.81, *SE*=.075; *p*=.058, approaching significance). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.010).

Message Preferences. When we presented participants with all stimuli and asked them to rank order the messages based on how well they believed the messages would motivate protective action (*N*=377), most ranked Condition 1, the "protect yourself" message (*n*=270, 72%) highest, followed by Condition 2, the "be aware" message (*n*=107, 28%).

Summary. The "protect yourself" message was associated with better outcomes compared to the "be aware" message and a large majority ranked it as more effective.

Experiment 5

Experiment 5 compared three different stimuli communicating different levels of earthquake intensity to the standard ShakeAlert messages. ANOVA results indicated significant differences by condition in levels of message understanding (F(3, 497)=2.972, p=.031), belief (F(3, 497)=5.984 p<.001), personalization (F(3, 497)=11.836, p<.001), milling (F(3, 497)=3.327, p=.020), and source credibility (F(3, 497)=2.840, p=.037). See Table 13.

There were no significant differences for deciding, response efficacy, self-efficacy, or affect.

Table 13. *Experiment 5: ANOVA Results for Level of Earthquake Intensity*

Outcome	Type III Sum of Squares	Mean Square	*F* *(DF=3)*	Sig.	Partial Eta Squared
Understanding	6.663	2.221	2.972	**.031***	.018
Belief	13.224	4.408	5.984	**<.001***	.035
Personalization	34.564	11.521	11.836	**<.001***	.067
Deciding	3.771	1.257	1.134	.335	.007
Milling	3.568	1.189	3.327	**.020***	.020
Source Credibility	7.440	2.480	2.840	**.037***	.017
Response Efficacy	1.498	.499	.645	.586	.004
Self-Efficacy	1.065	.355	.391	.760	.002
Affect	2.877	.384	.384	.765	.002

Understanding. Respondents who received the strong shaking message (Condition 4) showed significantly greater levels of message understanding (M=3.80, SE=.073) compared to those who received the weak shaking (Condition 2) (M=3.57, SE=.080; p=.037) and the moderate shaking (Condition 3) (M=3.56, SE=.078; p=.023). Similarly, respondents who received the standard message (Condition 1), with no MMI information, showed significantly greater levels of message understanding (M=3.79, SE=.079) compared to those who received the moderate shaking (Condition 3) (M=3.56, SE=.078, p=.036) and weak shaking (Condition 2) (M=3.57, SE=.080; p=.054, approaching significance) messages. According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial $\eta 2$=.018). There were no significant differences between the standard message (Condition 1) and the strong shaking message (Condition 4).

Belief. Respondents who received the strong shaking message (Condition 4) showed significantly greater levels of message belief (M=4.08, SE=.072) compared to those who received the weak shaking message (Condition 2) (M=3.77, SE=.080; p=.004) and the moderate shaking message (Condition 3) (M=3.75, SE=.078; p=.002). Similarly, respondents who received the standard message (Condition 1), with no MMI information, showed significantly greater levels of message belief (M=4.09, SE=.078) compared to those who received the weak shaking (Condition 2) (M=3.77, SE=.080; p=.004) and moderate shaking (Condition 3) (M=3.75, SE=.078; p=.002) messages. According to Cohen (1988), the overall effect size for this outcome is considered "small" to "medium" (Partial $\eta 2$=.035). There were no significant differences between the standard message and the strong shaking message (Condition 4).

Personalization. Respondents who received the strong shaking message (Condition 4) showed significantly greater levels of personalization (*M*=3.80, *SE*=.083) compared to those who received the weak (Condition 2) (*M*=3.20, *SE*=.092; *p*=.001) and moderate (Condition 3) (*M*=3.27, *SE*=.089; *p*=.001) shaking messages. Similarly, respondents who received the standard message (Condition 1), with no MMI information, showed significantly greater levels of personalization (*M*=3.70, *SE*=.090) compared to those who received the weak (Condition 2) (*M*=3.20, *SE*=.082; *p*=.001) and moderate (Condition 3) (*M*=3.27, *SE*=.089; *p*=.001) shaking messages. According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.067). There were no significant differences between the standard message (Condition 1) and the strong shaking message (Condition 4).

Milling. Respondents who received the strong shaking message (Condition 4) showed significantly lower levels of milling (i.e., less response delay) (*M*=1.44, *SE*=.050) compared to those who received the weak shaking message (Condition 2) (*M*=1.62, *SE*=.056; *p*=.008). Similarly, respondents who received the standard message (Condition 1), with no MMI information, showed significantly lower levels of milling (*M*=1.41, *SE*=.054) compared to those who received the weak (Condition 2) *(M*=1.62, *SE*=.056; *p*=.008) and moderate (Condition 3) (*M*=1.56, *SE*=.089; *p*=.061, approaching significance) shaking messages. According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.020). There were no significant differences between the standard message (Condition 1) and the strong shaking message (Condition 4).

Source Credibility. Respondents who received the strong shaking message (Condition 4) showed significantly greater levels of source credibility (*M*=4.08, *SE*=.078) compared to those who received the moderate shaking message (Condition 3) (*M*=3.79, *SE*=.085; *p*=.014). Similarly, respondents who received the standard message (Condition 1), with no MMI information, showed significantly greater levels of source credibility (*M*=4.09, *SE*=.085) compared to those who received the moderate shaking message (Condition 3) (*M*=3.79, *SE*=.085; *p*=.015). According to Cohen (1988), the overall effect size for this outcome is considered "small" (Partial η2=.017). There were no significant differences found between the standard message (Condition 1) and the strong shaking message (Condition 4).

Message Preferences. When we presented participants with all stimuli and asked them to rank order the messages based on how well they believed the messages would motivate protective action (*N*=380), most ranked Condition 4, the strong shaking message (*n*=242, 64%) highest, followed by the moderate shaking message (Condition 3) (*n*=70, 18%), and the weak shaking message (Condition 2) (*n*=68, 18%). The Standard message condition (Condition 1) was not included in the ranking task.

Summary. The strong shaking message and the standard ShakeAlert message had better outcomes than the light and moderate shaking messages. The majority of participants rated the strong shaking message as most effective at motivating protective action.

Experiment 6

Experiment 6 compared four different stimuli communicating different message content foci, including the Standard message (control), and a focus on the hazard, consequences, and recommended guidance. The results show no significant differences in any of the outcome variables. See Table 14.

Table 14. *Experiment 6: ANOVA Results for Varied Message Focus*

Outcome	Type III Sum of Squares	Mean Square	*F* *(DF=3)*	Sig.	Partial Eta Squared
Understanding	.243	.081	.117	.950	.001
Belief	1.753	.584	.790	.500	.005
Personalization	2.525	.842	.984	.400	.005
Deciding	5.182	1.727	1.719	.162	.010
Milling	1.004	.335	1.010	.388	.006
Source Credibility	1.116	.372	.460	.710	.003
Response Efficacy	3.269	1.090	1.530	.206	.009
Self-Efficacy	2.797	.932	1.052	.369	.006
Affect	1.019	.340	.128	.944	.001

Message Preferences. When we presented participants the stimuli and asked them to rank order the messages based on how well they believed the messages would motivate protective action (*N*=384), most ranked Condition 4, focusing on protective action guidance, highest (*n*=192, 50%), followed by Condition 2, focusing on the hazard, (*n*=106, 28%), and Condition 3, focusing on the impact (*n*=86, 22%). The Standard message condition (Condition 1) was not included in the ranking task.

Summary. In the context of earthquake early warning, with extremely immediate impact, there were no significant differences between messages that provided additional information about the hazard, the impact, or guidance. The message with additional guidance information was ranked as most effective by a large majority, however.

Perceived Costs

Perceived costs of receiving EEW messages were examined to identify potential barriers to using EEW services (see Table 15). Just over half agreed (somewhat or strongly) that they might receive an EEW message after shaking had begun and would be unable to respond (52%), and that they might not be able to react in time even if they received the message before shaking began (51%). Almost half agreed that an EEW message might say “strong shaking”, but the shaking might actually be very small (47%). Almost half (47%) agreed that significant danger or damage would occur, and 45% agreed that despite receiving an EEW message, they might not experience any shaking afterward. Just over half (51%) agreed they might not notice the EEW message. Just over a quarter (29%) agreed they would not know what to do if they received an EEW message, and 37% agreed that people around them would not know what to do.

Table 15. *Perceived Costs of Receiving Earthquake Early Warning Messages (N=2,401)*

	Now that you've had a chance to react to specific messages, we'd like to ask you about early earthquake warning messages in general. When you receive an earthquake early warning message, to what extent agree or disagree with each of the following statements?	Strongly Disagree %	Somewhat Disagree %	Neither Agree nor Disagree %	Somewhat Agree %	Strongly Agree %
1	I might receive an earthquake early warning message after the shaking has started, and not be able to respond.	6	8	34	30	22
2	I might not be able to react in time, even if I get an earthquake early warning message before the shaking starts.	6	12	31	32	19
3	The earthquake early warning message might say 'strong shaking', but in reality, the shaking might be very small.	5	9	39	29	18
4	I believe that significant danger or damage would occur from the shaking that came after an earthquake early warning message.[1]	10	16	27	24	23
5	Despite receiving an earthquake early warning message, I might not experience any shaking occurring afterward.	6	12	37	28	17
6	I might not notice it (i.e., not see or hear the earthquake early warning message).	5	10	34	30	21
7	I would not know what to do if I received an earthquake early warning message.	25	22	24	18	11
8	The people around me would not know what to do and I would have to help them.	13	16	34	23	14

[1] A total of 13 participants skipped this question (*N*=2,388).

Focus Groups

Results of the focus groups are presented below.

Response to Initial EEW "Protect Yourself" Message

The initial response to "protect yourself" message was consistent across all three focus groups: messages lacked enough information to satisfy the message receiver's needs for certainty about the time, location, and severity of the potential event.

Time. In reference to **time**, participants were unclear about when they might feel shaking, by when they should take protective action, and how long that single event would last (several expressed concern about aftershocks and tsunamis). In particular, many participants described EEW as earthquake prediction, lacking awareness or understanding of the monitoring, detection, and modeling processes that underlie the ShakeAlert system and messages sent. Because of this, there is also a misunderstanding about how long a person should expect to wait before experiencing the earthquake, and thus, how long to expect to take a protective action. Some wondered if a message is sent 10, 30, or even 60 minutes before an earthquake is "predicted" to occur.

Summary. The lack of understanding about the relationship between earthquake detection and the dissemination of an EEW suggests that public education may be valuable for increased understanding of message timing.

Location. In reference to **location**, participants were unclear about what areas were affected by the earthquake and their location respective to the earthquake epicenter. While most assumed that receiving a message indicated that they were in the area that would experience shaking, some referenced EEW as a type of app, such as an alerting app that they had previously downloaded, that was not location-aware. Because ShakeAlerts sent via IPAWS will be distributed to all cell phones that are enabled to receive WEA messages and they will be sent only to those within the vicinity of activated cell towers, the system does not require opting in and will only send messages to phones within the geographical footprint of the earthquake. Absent an understanding of WEA, some participants related the idea of ShakeAlert to an app-based alerting tool that might notify them of an earthquake even when they are traveling and are away from the area at risk.

Summary. The lack of understanding about the relationship between ShakeAlert messages disseminated via apps or WEA suggests that public education may be valuable for increased understanding of the location of the threat relative to those receiving an alert.

Severity/Intensity. In reference to **severity**/**intensity**, participants were mostly concerned about how much shaking they should expect (intensity) and whether it is enough to prompt them to take protective action. Because most of our participants had prior earthquake experience (described as being fairly mild in nature) they frequently did not consider DCHO a suitable response unless there was an indication that the event warranted protective action. Mild earthquakes were perceived as being events that required little response; without knowing the expected intensity, some focus group members reported being hesitant to take the DCHO action.

Summary. The lack of understanding about the thresholds that must be reached prior to triggering an earthquake early warning suggests that public education may be valuable for increased understanding of the conditions under which a ShakeAlert EEW will be issued. Messages issued via apps, with varying thresholds for dissemination, may confound the concerns raised by focus group participants.

While there were many comments about time, location, and severity, many participants did indicate that receiving a "protect yourself" message would prompt some form of action such as protecting oneself, others, or both. Many said that they would follow the instructions, but just as many said that they would go outside and away from the building that they would likely be occupying at the time they received the message.

Response to Initial EEW "Be Aware" Message

Initial "Be Aware" Message. The initial response to the "be aware" message was consistent across all three focus groups. Importantly, there were no discernable differences between what participants said about the "be aware" message and the "protect yourself" message. Participants had similar concerns about the lack of specificity around time, location, and severity and they indicated that they would likely protect themselves by following the instructions or by moving away from anything that might fall (such as a building collapse).

Summary. The initial response to the "be aware" message presented in the scenario suggests that message receivers interpret a "be aware" message as an something to be acted upon. Because the "be aware" message instructs receivers to drop, cover, and hold on, there is little distinguishing it in practice from a more actionable "protect yourself" message.

Response to Shaking Following the EEW

After viewing one of the two initial messages, focus groups were informed about the amount of shaking they experienced: no shaking, minimal shaking, or strong shaking.

No Shaking. In response to **no shaking** members of both the "protect yourself" and "be aware" focus groups had similar thoughts and responses (no discernable qualitative differences). Some thought that no shaking after receiving an alert meant that the message was false – that the system was hacked or broken, or that the earthquake occurred but it was not close enough to feel. Others responded to learning that no shaking had occurred with a sense of relief – that they "got lucky." However, the initial message did prompt many focus group participants to remain alert to future shaking events as they wondered if something was still coming.

Minimal Shaking. In response to **minimal shaking** members of both the "protect yourself" and "be aware" focus groups had similar thoughts and responses (no discernable qualitative differences). In this case, the experience of receiving an alert followed by the experience of shaking validated ShakeAlert as an authentic and useful tool to inform people of a potential hazard.

Strong Shaking. In response to **strong shaking** members of both the "protect yourself" and "be aware" focus groups had similar thoughts and responses (no discernable qualitative differences). In this case, participants in both groups were appreciative of the initial message that would prompt awareness and, in some cases, action.

Following all three shaking type outcomes, focus group members asked for more information about the initial earthquake (location and impacts) and, in the case of strong shaking, requested a second message describing secondary impacts such as potential for aftershocks or a tsunami.

Response to EEW 6 Months Later

Focus group participants were then asked to share their thoughts in response to a new EEW message for a second earthquake event six months later.

No Shaking. For participants who experienced **no shaking** six months earlier, there were no discernible differences between those who received a "protect yourself" or a "be aware" message. Those who said they would respond in the first instance by taking protective action said they were likely to respond similarly in this second instance. Some also indicated that they learned from the prior event that they would look for additional information (environmental or social) to validate that this message required a response prior to taking action.

Summary. Message receivers who receive multiple EEWs absent the experience of shaking may find that they have less trust in the system.

Minimal Shaking. For participants who experienced **minimal shaking** six months earlier, there were no discernible differences between those who received a "protect yourself" or a "be aware" message. However, the prior experience of receiving an alert reinforced system credibility and validated the need to take protective action. Participants remained interested in knowing the intensity/severity of this new earthquake event. Some participants verbalized concerns about aftershocks and those in coastal areas asked about tsunami risk.

Summary. Receipt of an EEW prior to experiencing shaking, regardless of level type ("protect yourself" or "be aware") reinforces perceptions that EEW is a successful and credible alerting mechanism for earthquake hazards.

Strong Shaking. For participants who experienced **strong shaking** six months earlier, there were no discernible differences between those who received a "protect yourself" or a "be aware" message. Similar to participants in the minimal shaking groups, having the prior experience of an accurate alert reinforced system credibility. A common response across both groups was "the first alert was correct, I will take action."

Summary. Correct/accurate alerts that demonstrate the ability of the system to detect and disseminate alerts before shaking is felt will increase trust in the system and in the likelihood that people will take action.

Bi-Level Comparison

"Be Aware" and "Protect Yourself" Side-by-Side Comparison. Focus group participants were then shown both messages, "protect yourself" and "be aware," side-by-side. An explanation was provided about the conditions under which each message would be sent (magnitude) and then they were asked to compare the two messages.

Participants raised the most questions about the "be aware" message, focusing on the imprecision of the words "be aware" and "may occur" (uncertain) in contrast with the statement that shaking was detected (certain). Participants especially wondered what actions receivers of the "be aware" message were supposed to take. Because the "be aware" message includes the instructions to "drop, cover, and hold on," message receivers wondered if they were supposed to take notice of the environment around them (be aware) or to take protective action (DCHO). In both cases, message receivers still requested more information about the time, location, and severity/impact.

Importantly, as identified in response to the scenarios above, focus group participants were unlikely to focus on the specific words in each message until they were side-by-side. During the scenarios, participants responded primarily to the certainty of the hazard (earthquake detected) and the recommended protected actions (DCHO). As participants noticed the differences in the message content, they made suggestions about how to differentiate them visually, such as by changing the message colors or the style of font, in order to draw more attention to those conditions that require action.

Summary. Message receivers are not likely to recognize the difference between the two alert types in practice, especially if they are not side-by-side. Both message types are likely to prompt similar outcomes: action by some and no action by others. The prior experience of receiving an accurate alert – that is, one that is received prior to feeling shaking – is likely to affect trust in the system over time. Messages that hedge with uncertainty (may occur) are likely to be more meaningful to scientist communicators than to message receivers.

How to Express Time

The expression of time was explored by viewing three stimuli individually and then side-by-side. All focus group participants who viewed the time animations shared appreciation for the additional information. Participants explained that they thought animations were both visually appealing and might help with language barriers. By providing a countdown, participants felt a sense of greater urgency. The inclusion of time addressed participant questions about how quickly they should expect to feel earth shaking and whether their protective action response should occur within seconds, minutes, or hours. However, some participants did raise concerns about the ability for the ShakeAlert system to be precise with time relative to impact (down to the second). Some also asked for clearer labels (indicating that the timer was counting down in seconds, not another measure of time), and asked for a larger font size for those with viewing impairments.

Angled Bar Countdown. In this version, participants viewed a graph on a black background containing a bar that "filled up" at an increasing angle, from left to right, with a red color as the time counted down. Participants found this animation to be "easy to follow" and they explained that the way the graph filled up as the time counted down created a kind of tension for the viewer as it demonstrated the increasing intensity of the earthquake.

Thermometer/horizontal countdown. In this version of the countdown, the bar starts out as solid black and "empties out," to display a red bar, from right to left, as time counts down.
Some participants discussed the orientation of the color black emptying the image (moving from right to left) as unusual; others found it consistent with the countdown.

Analog Clock Countdown. In this version, a hand sweeps around the clock, visually ticking off the seconds as the clock face changes color from black to red. Some participants described the clock and its ticking hand as a distraction to the message receiver. Others liked the change in color, the familiar motion, and the ticking as it appeared to be clear and visually compelling.

Side-by-Side Comparison. When comparing the three stimuli side-by-side, participants were asked "which message would get you to take action the fastest." Participants preferred the angled bar countdown the most because of the way that the bar filled up with red, suggesting a sort of increasing urgency visualized as color rising with time. The analog clock was preferred second and the thermometer/horizontal countdown as preferred third.

Summary. Animated countdowns that include color signals can be useful to signal urgency, but may also delay action among message receivers who become distracted. The angled bar countdown was described as creating a sense of tension that signaled a need to act quickly.

How to Express Location

The expression of location was explored by presenting a series of maps to focus group participants. In most cases, the inclusion of a map was appreciated because it was perceived to help the message receiver to understand the location of the epicenter and, in some cases, could help the message receiver identify their location relative to the epicenter. However, the lack of a legend in all three visuals was a drawback to interpretation. Furthermore, participants expressed concerns about privacy that may be given up in order to get precise location information.

Pulsing Rings. In this version, rings were shown in such a way as they appeared to be pulsing from the epicenter of the event. This animation drew the attention of focus group participants due to clarity of the presentation (lacking additional shading or color greyscale) and was described as being easy to view. However, the animation was also perceived as being a potential distraction, (especially if the receiver was driving at the time). Participants also raised concerns about data use due to the additional memory needed to power the animation.

Static Map in Greyscale. In this static map version, circles increased in size as they moved further away from the epicenter and were shaded in greyscale. The use of greyscale was viewed positively by focus group participants because the shading appeared to show areas of impact. However, the lack of a map legend left viewers guessing if different shades of grey meant different levels of severity.

Static Map in Greyscale with Location Marker. In the third version, the same static greyscale map in the prior stimuli was presented but included a location marker to indicate where the message receiver was located. While some focus group participants preferred the inclusion of a personal location marker, others were concerned because a map that included personal location information indicates that the system must be tracking the message receiver, raising questions about privacy. The greyscale also was not labeled and there were concerns that some receivers would not be able to interpret the map information accurately and quickly.

When comparing the three stimuli side-by-side, participants were asked "which message would get you to take action the fastest." We tallied their preferences and found that they preferred the static map in greyscale (without location marker) first. This was followed by preference for the pulsing rights and the static map with location marker.

Summary. Maps are preferred with warning messages because they are thought to provide additional useful information. Participants preferred static maps that did not include personal location information that suggested a violation of privacy.

Intensity/Magnitude

Focus group participants viewed three versions of stimuli that expressed the expected severity/intensity of the earthquake. The first version used categorical adjectives that are more subjective in nature, the second described what they would see/feel in literal terms, the third included both descriptive information and an image indicating scientific measurement in Roman numerals (Modified Mercalli Scale). In general, participants were pleased to know more about the intensity, but the categorical description of the shaking, the message length, and the inclusion of a scientific figure were each described as being problematic.

Expect Strong Earthquake. Focus group participants found the inclusion of the word “strong” to be motivating, expressing urgency and significance, and was informative. However, not all persons receiving the message would know what “strong” means. Several participants also suggested that the style of this message should differ from its current presentation so that the most important information is in bold or placed at the top of the message (such as Emergency Alert: **Strong Earthquake**)

Literal description of shaking experience “Expect Some Heavy Furniture to Move.” Focus group participants expressed concern about the amount of text included in this message. While it clearly articulated what a message recipient could expect in their environment, it was long and provided too much detail for most message receivers.

Scientific Presentation using MMI. There were no positive comments about this message though one person said they liked it without provide additional detail. Other focus group participants said that the message was also too long. Importantly, the inclusion of “MMI V” was interpreted by some as a representation of the Richter Scale, and was described by others as “technical jargon,” that would delay action. One person offered that if a graphic/icon is to be included, an image of DCHO might be a better option.

When comparing the three stimuli side-by-side, participants were asked “which message would get you to take action the fastest.” We tallied their preferences and found the message with the literal description of shaking “expect some heavy furniture to move” was most preferred, followed by the categorical description of shaking and the inclusion of scientific terminology (MMI) last.

Summary. Describing intensity in physical, literal terms can help message receivers to envision the potential impact of the earthquake. However, there were concerns about additional detail that adds to message length and complexity of information, both factors that could delay action as receivers spend more time reading and interpreting the message.

Discussion

Hypotheses

A discussion of the three main hypotheses follows.

H1: *Providing greater specificity about the earthquake location (epicenter) will lead to better message outcomes.* Hypothesis 1 was confirmed. Experiment 1 results showed that providing increased specificity about the earthquake location by indicating the respondent's distance in miles from the epicenter was associated with higher levels of message understanding, personalization (approached significance), deciding, and affect (approached significance).

H2: *Providing greater specificity about the earthquake time to arrival (countdown) will lead to better message outcomes*. Hypothesis 2 was confirmed. Although Experiment 2 showed that increased specificity in time to impact did not result in significantly different message outcomes (other than affect), Experiment 3 showed that individuals who received a message indicating a long countdown (15 seconds) had significantly higher levels of message belief than those who received no countdown or a short countdown (approaching significance). That is, participants' message belief increased with the length of the countdown.

H3: *Providing greater specificity about the earthquake consequences (intensity) will lead to better message outcomes.* Hypothesis 3 was confirmed. Experiment 5 indicated significantly higher levels of message understanding, belief, personalization, and source credibility, and lower levels of milling/response delay, among those who viewed a message describing strong shaking intensity, compared to those who viewed messages with weak or moderate shaking intensity. That is, people responded appropriately to the more urgent, higher shaking intensity message. Noteworthy is the fact that participants who viewed the Standard message, which did not mention MMI but did instruct people to Drop, Cover, and Hold On, had similar outcomes as those who viewed the strong shaking intensity message. Thus, the Standard ShakeAlert message seems to communicate a similar level of threat and urgency as do messages indicating strong shaking intensity (MMI VI), despite the fact that such alerts may be for lower intensity earthquakes. Messages that include information about shaking intensity help people assess their risk and modify their response.

Integrated Findings

This research provided a unique opportunity to combine multiple methods to examine the effect of communicating earthquake early warning information with greater specificity. We used experiment data on message outcomes, rank ordering of messages along with open-ended explanations for respondent preferences and focus group data to examine a key set of questions.

Question 1: Are earthquake early warning message outcomes better when hazard location (i.e., earthquake epicenter) is communicated via text, maps, or a combination of both compared to a standard message that does not indicate hazard location?

To answer this question, we combined information from Experiment 1, the message ranking data and associated open-ended text, and focus group data addressing animated maps.

In Experiment 1, we compared three approaches to communicating earthquake location—adding the number of miles between the participant and epicenter, including a map showing this visually, and including both the number of miles between the participant and epicenter and a map—to the standard ShakeAlert message. Participants who viewed the message that included the number of miles between the participant and epicenter (Condition 2) had significantly higher levels of message understanding and deciding compared to the Standard message (Condition 1) and the combined message that communicated distance by adding the number of miles and a map (Condition 4). Participants who viewed the message that included the number of miles between the participant and epicenter (Condition 2) also had higher levels of message personalization (approaching significance) than both the message that included a map (Condition 3) and the message that included the number of miles between the participant and epicenter and a map (Condition 4). That is, messages that added *only* a map had worse message outcomes than the message that simply expressed proximity to the hazard (number of miles between the participant and epicenter). It is interesting to note that when viewing the messages side-by-side, the majority of participants (57%) ranked the message that added number of miles between the participant and epicenter and included a map (Condition 4) highest. In the open-ended comments, participants reported that they believed the additional information contained in the map would be useful because it included more content.

We explored these issues further in Focus Groups 2 and 5 (see Figure 9). In focus group discussions, when comparing three different maps, participants preferred a map similar to the map stimulus used in the experiments, but without their personal location identified, expressing privacy concerns. They expressed confusion about the use of a hazard icon representing the earthquake (it was unfamiliar), and they were uncertain as to the meaning of the grey shading represented (they were uncertain if the shades represented more shaking intensity or impact).

Maps, if crafted well, have the potential to be instructive and help message receivers personalize information. In the case of extremely short-fuse hazards, such as earthquakes, it may be that there is not sufficient time to interpret visual map information, although participants may, in fact, think the information would be useful. Messages that simply state the proximity of the threat in textual content may mitigate against cognitive load, which may be heightened under conditions of imminent threat. It is important to note that participants were not asked to provide their interpretation of the meaning of "distance in miles from epicenter"; thus, it is unclear what meaning they make of this phrase and how they may connect it to level of shaking intensity or potential risk.

Question 2: Are earthquake early warning message outcomes better when time to impact is communicated via an analog clock or digital clock countdown compared to a standard message without a countdown?

To answer this question, we combined information from Experiment 2, the message ranking data and associated open-ended text, and focus group data addressing animated time.

In experiment 2, we compared two different approaches to communicating 10 seconds until impact (analog and digital clocks) to the standard ShakeAlert message, with no countdown. There were no significant differences other than in affect. When the messages were viewed side-by-side and participants were asked to rank order them based on their ability to motivate protective action, the message with the digital countdown was rated highest (43%), followed by the analog clock (32%), and no countdown (25%). Open-ended explanations for participants' rankings revealed that many preferred the digital countdown because unlike the analog clock, the digital clock was not perceived as "scary", “anxiety producing” “ominous”, “haunting”, did not represent “doom”, and was less likely to create panic. It is worth noting that these comments were made only after participants viewed the messages side-by-side, in relation to one another.

We explored animated countdowns further in the Focus Groups 1 and 4 (see Figure 8). Focus group participants preferred the stimulus that included the angled bar countdown that filled up with red as the seconds counted down. The use of color attracted attention, and this animation in comparison with the other conditions, was preferred because it created the greatest feelings of urgency.

Taken together, the findings seem contradictory in that participants in the experiments preferred the countdown that was less “scary”, while focus group participants seemed to prefer the countdown that was more so. Still, there were no significant differences between the Standard message and messages that added analog and digital clock countdowns other than higher positive affect. While different preferences were observed using different data collection methods, there was no evidence that presenting a countdown of any sort changed the way people responded to the message (other than by influencing affect). This is likely due to the extremely short time to impact in the earthquake context, and results may not apply to more extended warning contexts. For earthquakes, even with no countdown, participants are instructed to act immediately.

Question 3: Do earthquake early warning message outcomes vary across different lengths of time to impact?

To answer this question, we combined information from Experiment 3 with message preference data (rank order and open-ended responses explaining rank choices).

In Experiment 3, we compared message outcomes for the message with no countdown, a short countdown (5 seconds), and a long countdown (15 seconds). Those who viewed the message with the long countdown (Condition 3) had significantly higher levels of message belief compared to the other groups. When viewing the messages side-by-side, a majority of participants (56%) ranked the message with a longer time to impact (Condition 3) as most effective at motivating protective action. The open-ended responses explained the preference for a longer countdown by stating that “it gives people more time to prepare for a response” and to take action.

Taken together, we conclude that having a longer amount of time to respond may influence the way people perceive the threat. It is important to note that in this research, the “long” countdown was only 15 seconds. As ShakeAlert technology improves and where longer countdowns become more possible, the ways in which people respond to longer countdowns may differ from these results. Note, currently, there is one ShakeAlert-powered App provider that includes a countdown, although they post a disclaimer about its efficacy, as latencies have been noted as an issue.

Question 4: Do people respond appropriately to bi-level earthquake early warning messages (Protect Yourself v. Be Aware)?

To answer this question, we combined information from Experiment 4, message preference data (rank order and open-ended responses explaining rank choices) and focus group data addressing bi-level alerts.

In Experiment 4, we investigated how people respond to “bi-level” alerting by exposing participants to two conditions that included either the language “protect yourself” or “be aware.” Results showed that the “protect yourself” message resulted in significantly higher understanding, believing, deciding, source credibility, as well as higher response efficacy (approaching significance), and self-efficacy (approaching significance) than the “be aware” message. When viewing the two messages side-by-side, the majority of participants ranked the “protect yourself” message as more effective (71%) at motivating action than the be aware message. In the open-ended comments, they explained that “protect yourself” is a clear call to action telling people to take the threat seriously, and indicating that the threat is urgent, while the use of the words “be aware” were perceived as not motivating and actually confusing to message receivers.

In focus group discussions, we found that participants who viewed either EEW in response to a scenario did not describe any differences in the way that they understood or thought they might respond to the two messages. Both messages included the language, “Earthquake detected…Drop, Cover, Hold on” suggesting the need for action. When focus group participants viewed the messages side-by-side, however, they observed the difference between the two and expressed confusion about the purpose of the “be aware” message as well as dissatisfaction with potentially receiving messages instructing them to “be aware.”

Taken together, these results show that the “protect yourself” language was strongly preferred and yielded markedly better message outcomes, indicating that participants correctly interpreted the higher level of potential threat. In contrast, the results suggest that the intent of the “be aware” language may not be readily understood to message receivers in a real event and may possibly lead to negative reactions among message receivers.

Question 5: Do earthquake early warning message outcomes vary across different levels of shaking intensity?

To answer this question, we combined information from Experiment 5, message preference data (rank order and open-ended responses explaining rank choices) and focus group data addressing the inclusion of MMI information.

In experiment 5, we compared three messages with different amounts of shaking indicated and described in text (MMI III weak, V moderate, and VI strong). The message indicating strong shaking (MMI VI) resulted in significantly greater message understanding, believing, and personalization compared to the other two other messages with lower shaking intensities, and lower milling or less response delay (approaching significance) and higher source credibility (approaching significance) than the message with the weak shaking. When asked to rank order the three messages, almost two-thirds of the participants ranked the message with strong shaking intensity as most effective (63%). Notably, when they viewed the three messages side-by-side, quite a few participants expressed that the three messages were the same, although their actual message outcomes in the experiment were significantly better for Condition 3 (strong shaking MMI VI).

In Focus Groups 3 and 6 (Figure 10), participants expressed strong negative reactions to the inclusion of the MMI icon with the Roman numeral indicating intensity level. They did not understand what MMI meant, felt like it was scientific jargon, and reported that the use of jargon was not helpful.

Taken together, we found that the higher level MMI message (strong shaking MMI VI) had better message outcomes than lower levels (moderate MMI III and moderate MMI V). Thus, MMI VI may serve as a "tipping point" for "activating" message response. At lower MMI levels, people may not be sufficiently activated, and they may wait for external cues (i.e., ground motion) to see how "big" the earthquake feels before deciding to act. However, the use of the acronyms or numerals to indicate shaking intensity may not be well understood without accompanying descriptive text.

Question 6: Do earthquake early warning message improve when additional information about the hazard, impact, and recommended guidance are included?

To answer this question, we combined information from Experiment 6, message preference data (rank order and open-ended responses explaining rank choices) and focus group data addressing the inclusion of information focusing on either the hazard or the impact.

In Experiment 6, we added information to the standard ShakeAlert message and compared message outcomes for three messages with greater specificity about the hazard, its impact, and recommended guidance. We added language about the hazard by describing the amount of shaking expected ("expect strong shaking"), language about the impact by describing the likely impacts people may observe ("expect some heavy furniture to move"), and language about guidance by describing the protective action in greater detail than "drop, cover, and hold on" ("to protect yourself, drop close to the ground, cover your head and neck, and hold onto something sturdy"). It is important to note that in Experiment 6, all three messages included at least basic information about drop, cover, and hold on. We found no differences in outcomes for the three message conditions. Initially, we did not include the standard ShakeAlert message as a control in Experiment 6, and we later added 121 additional cases of participants who viewed the standard ShakeAlert message to enable comparison. There were no significant differences in outcomes, however. Interestingly, when participants rank ordered the messages, half (50%) preferred the message with additional guidance (what to do) and half (50%) preferred a message with additional information about what to expect (either intensity or impact).

When considering focus group discussions about how to express hazard and impact, we found that preferences were evenly split across description of the shaking and impacts (Focus Groups 3 and 6, Figure 10), but there was a markedly lower preference for the message presenting intensity using MMI because it was viewed as too technical for receiver audiences.

Information about the hazard, impact, and guidance are interrelated, and message audiences need all three types of information in combination to make sense of what is happening and how to respond. For earthquakes, this must be done with the greatest economy of language, as is accomplished in the standard ShakeAlert message. For hazards with longer time to impact and longer message lengths, this information should be provided in sufficient detail to motivate and enable message receivers to take appropriate protective action.

Other Key Findings

1. *For earthquakes, communicating proximity to the epicenter works better than including a map.* Experiment results showed that messages that included maps had worse message outcomes than messages that indicated the participant's proximity to the earthquake epicenter (number of miles) in the message text.

2. *Stated preferences for the design of future warning messages may not align with design features that are associated with the best message response outcomes.* In other words, what people prefer may not always be what works best. For example, we found that participants preferred messages that included a map because they thought it would include useful information; however, messages that contained a map were associated with significantly *worse* message outcomes, including significantly lower message understanding and deciding and lower personalization (approaching significance) and more negative affect (approaching significance). Do not assume that adding more information and more types of info (i.e., text, numbers, icons, maps, sounds, haptics) is always better.

3. *People correctly interpret the greater call to action in "protect yourself" messages compared to "be aware" messages.* The "protect yourself" message was associated with significantly higher message understanding, belief, deciding, and source credibility, and higher levels of response efficacy (approaching significance) and self-efficacy (approaching significance). When viewed side-by-side, a majority of experiment participants considered the "protect yourself" messages better at motivating protective action. Focus group participants did not distinguish "protect yourself" and "be aware" messages until they viewed them side-by-side, and then reported that they did not want to receive "be aware" messages because they were too easily confused with "protect yourself" messages and because they were a "waste of time." If "be aware" messages are adopted, they should look quite different from "protect yourself" messages that communicate risk; they should look and feel like a different type of communication.

4. *Some people do not understand how earthquake early warning works, and consequently will not be able to properly interpret time to impact.* Some participants indicated they expected the warning to occur several minutes or longer prior to impact and viewed EEW as a prediction. Without knowledge of the system, message receivers may misunderstand the conditions under which messages are sent and actions are recommended.

5. *Some people do not understand and consider Modified Mercalli Intensity (MMI) levels overly technical jargon.* Participants reacted negatively to the Roman numerals representing MMI shaking intensity levels and reacted positively to the MMI descriptions of potential impact.

6. *Some people are not sure what to do when they receive an earthquake early warning message, suggesting the need for more directed education.* More than half (53%) indicated that they were uncertain or would not know what to do if they received an earthquake early warning message. This and other response costs may be potential barriers to EEW use.

7. *MMI VI seems to represent a "tipping point" level of anticipated shaking intensity that triggers significantly better message outcomes.* Outcomes for MMI III and V messages were not significantly different from one another, but both were significantly worse than those for the MMI VI message. Not including MMI information in EEWs seems to yield a similar response as indicating that strong shaking expected (MMI VI). This may have implications for how people respond to the standard ShakeAlert message over time, as they may become habituated to the DCHO call to action given that some such alerts will be followed by more moderate shaking.

8. *People have strong preferences for information including specific guidance.* Explaining how to "drop, cover, and hold on" led to higher mean scores for self- and response efficacy as well as deciding compared to simply telling people to "drop, cover, and hold on" but these differences

were not statistically significant. In an immediate impact context such as earthquakes, providing detailed guidance instructions appears to be of lesser value in motivating protective action than in other hazard contexts. This may also reflect familiarity with "drop, cover, hold on" guidance.

Limitations

Study limitations included the fact that data collection activities occurred in English only, and participant recruitment was limited to the U.S. West Coast. In addition, data were collected in a somewhat artificial virtual context. Furthermore, although we operationalized our study conditions/stimuli with input from USGS Social Science Working Group, we presented participants with only a limited number of map and countdown designs. Finally, our scales measured message outcomes such as how well people understood the message; however, for the milling construct, we only measured perceived milling, that is, how much people imagined they would delay before taking action.

Future Research Needs

Future research should develop and test stimuli created in other languages beyond English. The findings should be confirmed in real-world events and among those who are located outside of the area at risk. In addition, research should examine how ShakeAlert systems and communications may or may not translate to other systems outside the West Coast (e.g., google alerts). The role of maps should be examined for use in different hazard contexts, with more time to impact and different impact "footprints." Research should seek to apply, translate, and evaluate findings from this work, particularly in a tsunami context, where the footprint of impact is directed from the ocean onto landmass. Additional research should develop and evaluate the overall effectiveness and impact of "be aware" messages and messages sent at lower thresholds, especially in relation to concerns about over-alerting within the wider WEA system. What people do when they are presented with a countdown should be examined, as well as how people understand the concept of "distance from the epicenter" and the notion of communicating distance from the epicenter v. distance of the hazard from the users' location. The potential value of developing image and icon only messages that could transcend language and reading ability should be explored. Finally, the relative impact of providing increased specificity regarding the hazard, impact, and guidance, separately and in combination, should be tested in contexts that include longer messages.

Recommendations

Based on the findings of this multi-method, collaborative report, we offer the following recommendations:

1. ***Wireless Emergency Alerts (WEA) should remain limited to imminent threat alerts***. This type of alert should not be used for public education efforts, such as "be aware" or other types of messaging such as post-alert messaging. To prevent active disengagement, do not use "be aware" messages as a public education tool.

2. ***Create public education messages that introduce and explain the limitations of EEW***. This understanding is necessary so members of the public can properly interpret and respond to information about time to earthquake impact.

3. ***Use caution when including maps in messages about hazards with a very short time to impact.*** Although people may report a desire to have a map included in future warning messages, when participants were actually presented with information communicated via text, a map, and both text and a map, the messages that included maps yielded worse message outcomes.

4. ***Add information about the user's proximity to the earthquake epicenter to earthquake early warning messages***. Although participants preferred messages that included additional text and a map—both indicating their proximity to the epicenter—this preference did not correspond to experiment results. Those who viewed messages that included maps had worse outcomes (understanding, deciding, personalization, affect) than those who viewed the standard ShakeAlert message with additional text indicating their distance from the epicenter.

5. ***MMI descriptions can be used in earthquake early warning messages to communicate shaking intensity or hazard impact; MMI symbols should not be used.*** Including descriptions of impact for different levels of shaking intensity in earthquake early warning messages lead to appropriate differences in message outcomes, but when participants viewed acronyms (MMI) and Roman numerals, many were confused and did not understand their meaning.

6. ***The current standard ShakeAlert message includes brief but sufficient information about the hazard, its impact, and guidance.*** Telling people to drop, cover, and hold on in the standard ShakeAlert message was as effective as providing additional information about the hazard ("expect strong shaking"), its impact ("expect some heavy furniture to move, fallen plaster"), and guidance ("drop close to the ground, cover your head and neck, and hold onto something sturdy"). This greater specificity is likely more relevant for hazards with a longer time to impact; however, there were strong preferences for guidance information.

Project Data

Experiment data are housed at CSU Fullerton, Department of Public Health and are available for review upon request (contact Dr. Michele Wood, mwood@fullerton.edu).

Audio recordings of focus group discussions have been destroyed to protect respondent privacy in accordance with IRB approved study protocol. Transcripts are housed at SUNY Albany and are available for review upon request (contact Dr. Jeannette Sutton, jsutton@albany.edu).

Bibliography

Publication Plan. We are finalizing submission of the following manuscripts for publication in academic journals in the coming months.

Publication # 1

Research Question:	What is the best way to communicate hazard location and time to impact in EEW?
Lead Author:	Sutton
Co-Authors:	Crouch, Huntsman, Waugh, Wood (alphabetical order)
Working Title:	Insights about communicating hazard location and time to impact from earthquake early warning
Data Source:	Experiment 1 and 2 data, and focus group transcripts
Target Journal:	*Journal of Applied Communication Research*

Publication # 2

Research Question:	How do members of the public understand and respond to “bi-level” earthquake early warning?
Lead Author:	Wood
Co-Authors:	Crouch, Huntsman, Sutton, Waugh (alphabetical order)
Working Title:	“Bi-level alerts and earthquake early warning: How increased hazard specificity impacts outcomes for immediate impact alerts”
Data Source:	Experiment 4, 5, and 6 data, and focus group transcripts
Target Journal:	*International Journal of Disaster Risk Reduction*

Publication # 3

Research Question:	What earthquake early warning messages best predict intentions to adopt protective behaviors via intermediary outcomes? Are there moderating effects from experience or risk perception?
Lead Author:	Huntsman
Co-Authors:	Crouch, Sutton, Waugh, Wood (alphabetical order)
Working Title:	“Earthquake early warning messages and intentions to adopt protective behaviors: An integrated PMT model”
Data Source:	Experiment 1-6 data
Target Journal:	*Risk Analysis*

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Appendix I

Outcome Measures

Understanding

After viewing this warning message, I understand…

1. What is happening.
2. The risks.
3. What to do to protect myself.
4. What location is affected.
5. Who the message is from.
6. When I am supposed to take action to protect myself.
7. How long I am supposed to continue taking action to protect myself.

Belief

After viewing this warning message, I believe that…

1. The earthquake is heading my way.
2. The message is trustworthy.
3. I know when I will be in danger.
4. I should take action to protect myself.
5. Taking protective action will make me safer.

Personalization

After viewing this warning message, I think that…

1. I might become injured.
2. People I know might become injured.
3. People I do not know might become injured.
4. I might die.
5. People I know might die.
6. People I do not know might die.

Deciding

After viewing this warning message, I believe that…

1. It will be easy to decide what to do.
2. I will be able to decide what to do quickly.
3. I can decide what to do with confidence.

Milling

If you received this message, how do you think you would respond?

1. Immediately protect myself from the earthquake.
2. Check in with others before protecting myself from the earthquake.
3. Wait to feel shaking before protecting myself from the earthquake.
4. Do nothing to protect myself from the earthquake.

Source Credibility

After viewing this warning message, I feel the source of the message…

1. Appeared to be reliable.
2. Appeared to be professional.
3. Appeared to be well-experienced.
4. Appeared to be trustworthy.
5. Appeared to be credible.
6. Appeared to be knowledgeable.

Response efficacy

After viewing this warning message, I feel…

1. I can mentally protect myself from an earthquake.
2. I can physically protect myself from an earthquake.
3. The message gives me useful information about the earthquake, even if I didn't feel the shaking.

Self-Efficacy

After viewing this warning message, I believe that…

1. I know what actions I should take.
2. I am confident I can act on the information.
3. I am capable of acting on the information.

Response Costs

When you receive an earthquake early warning message, to what extent agree or disagree with each of the following statements?

1. I might receive an earthquake early warning message after the shaking has started, and not be able to respond.
2. I might not be able to react in time, even if I get an earthquake early warning message before the shaking starts.
3. The earthquake early warning message might say 'strong shaking', but in reality the shaking might be very small.
4. I don't believe that significant danger or damage would occur from the shaking that came after an earthquake early warning message.
5. Despite receiving an earthquake early warning message, I might not experience any shaking occurring afterward.
6. I might not notice it (i.e., not see or hear the earthquake early warning message).
7. I would not know what to do if I received an earthquake early warning message.
8. The people around me would not know what to do and I would have to help them.

Affect

After receiving this message, I feel…

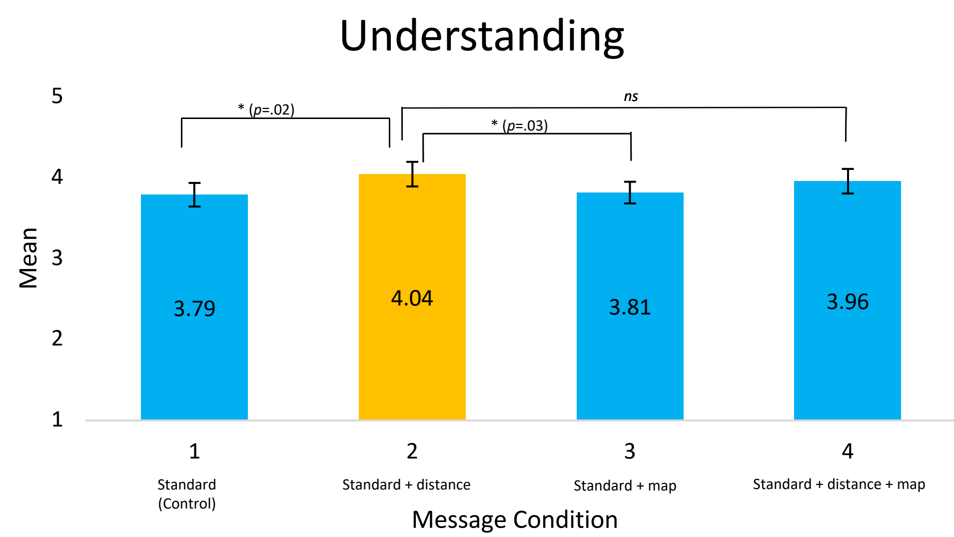
1. Worried - Assured
2. Fearful - Fearless
3. Anxious - At ease
4. Dread - Confident
5. Annoyed – Pleased

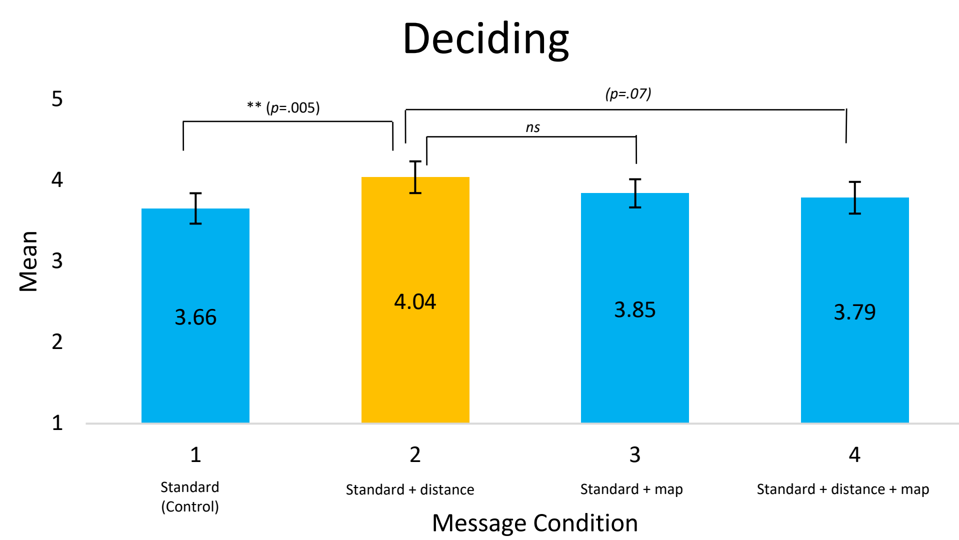
***Note**:* Items were measured on 1-5 Likert-type Scale (Strongly Disagree - Strongly Agree) except Milling (see Questionnaire Design section) and Affect, which was measured on a 7-point semantic differential scale.

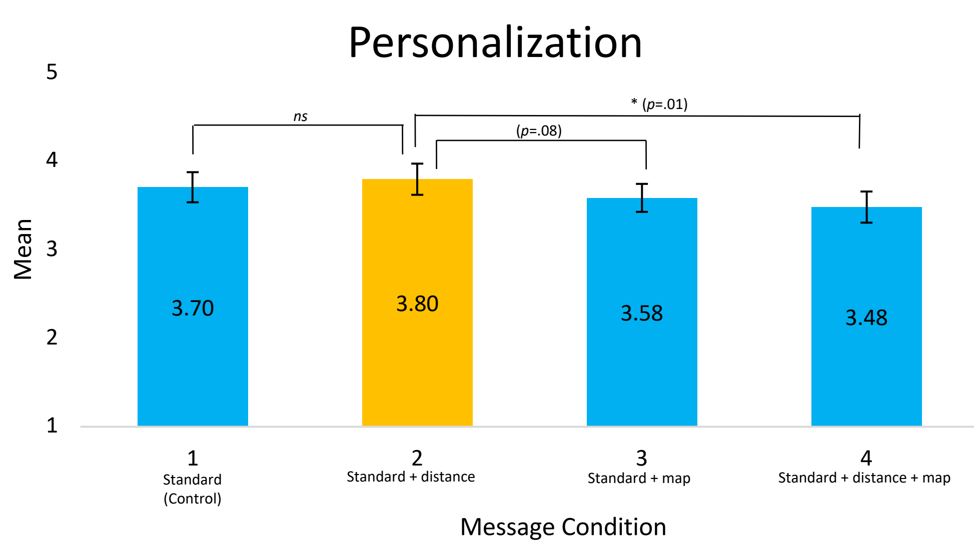
Appendix II

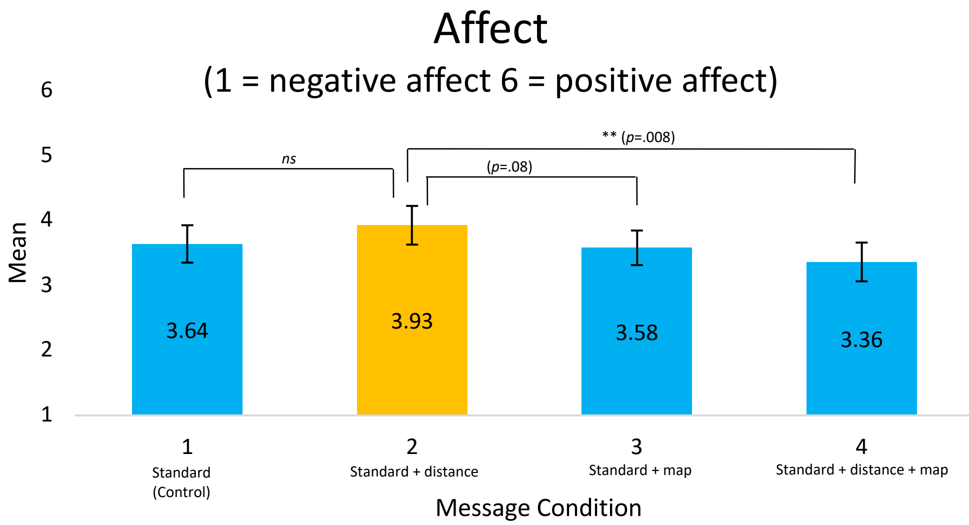
Bar Charts for Pairwise Comparisons

Experiment 1

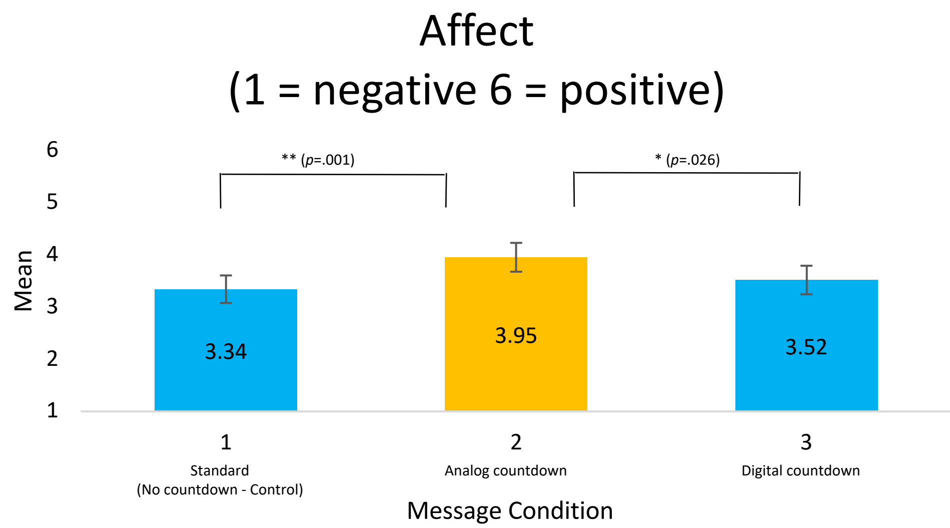




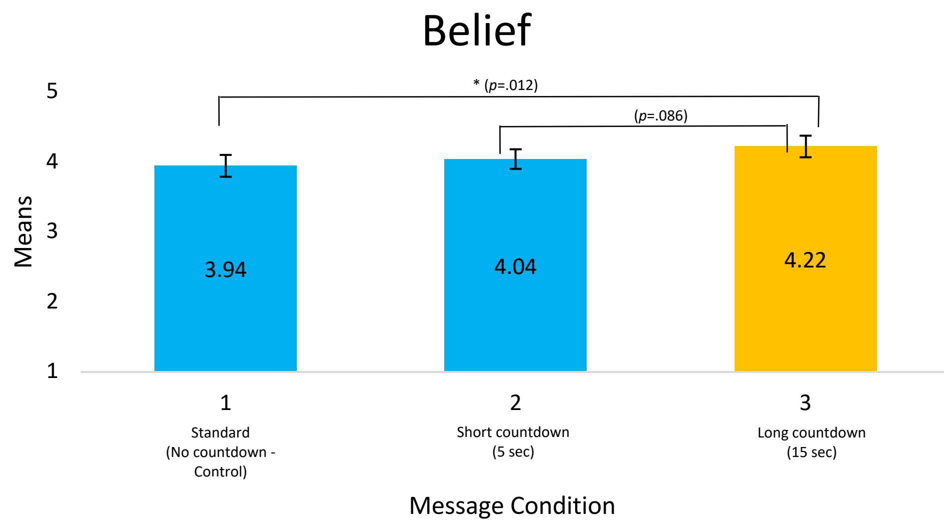


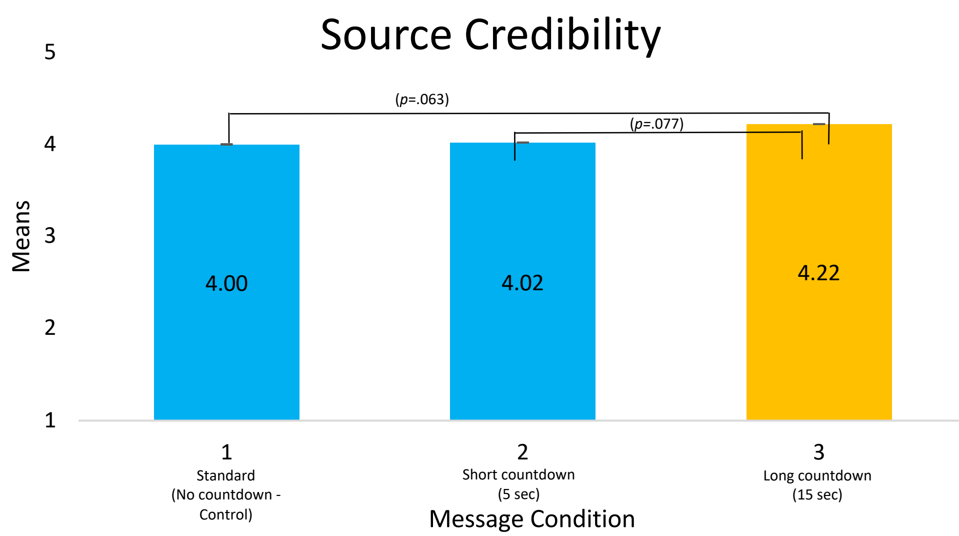

Affect
(1 = negative affect 6 = positive affect)
Mean
6
5
4
3
2
1
ns
(p=.08)
** (p=.008)
3.64
3.93
3.58
3.36
1
Standard
(Control)
2
Standard + distance
3
Standard + map
4
Standard + distance + map
Message Condition

Experiment 2

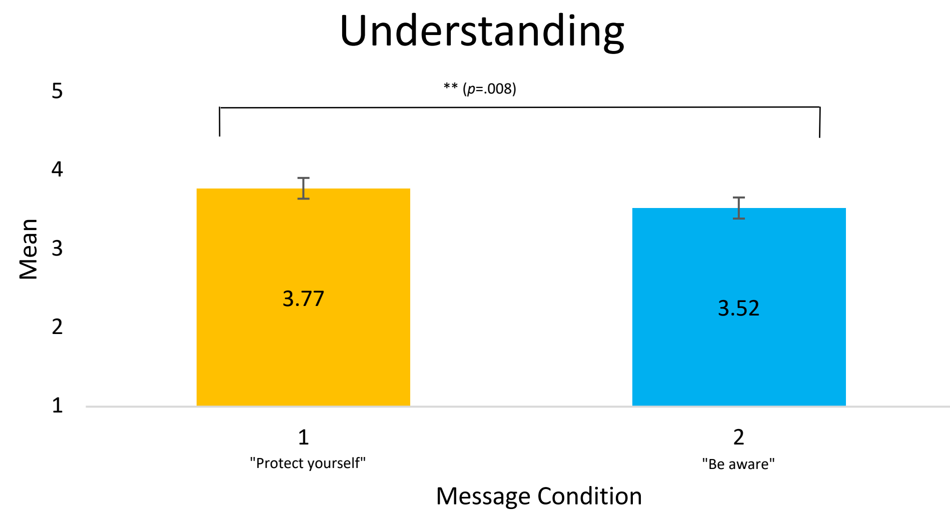


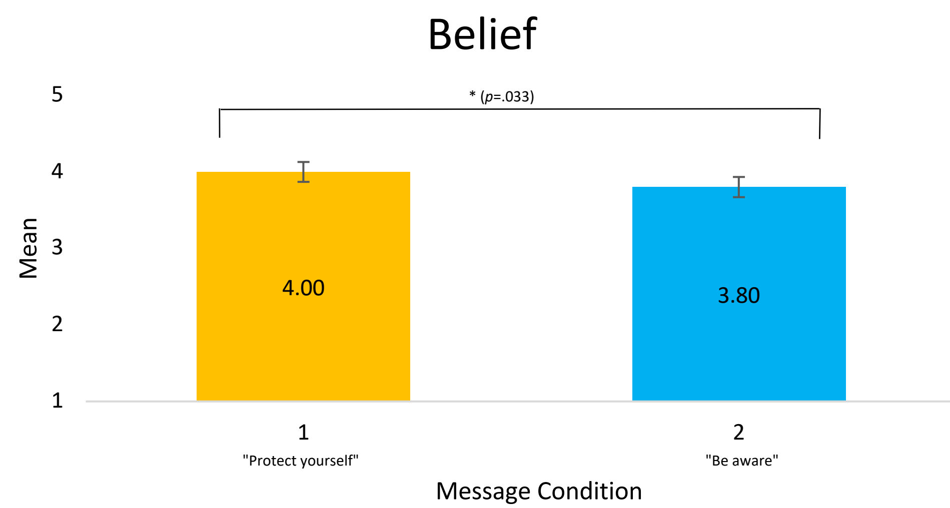
Experiment 3

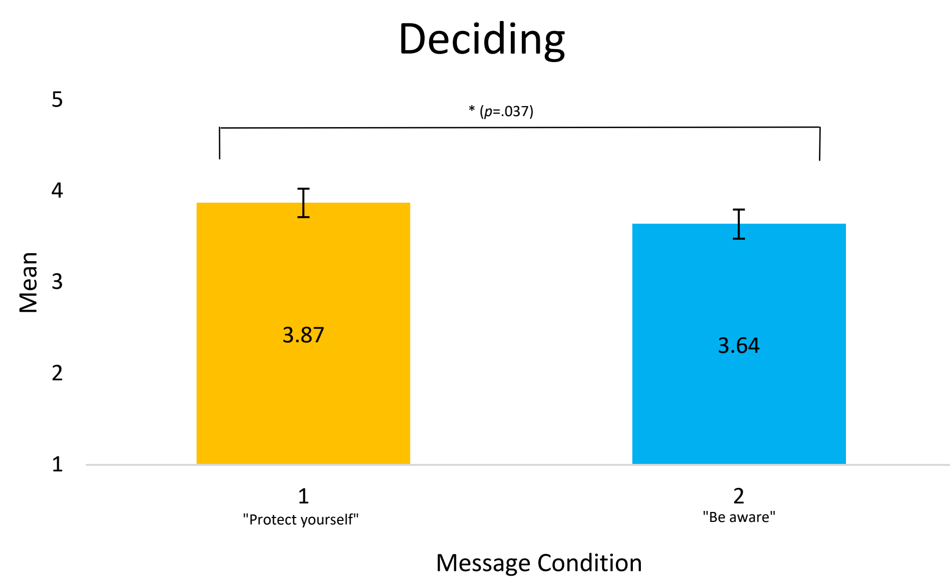


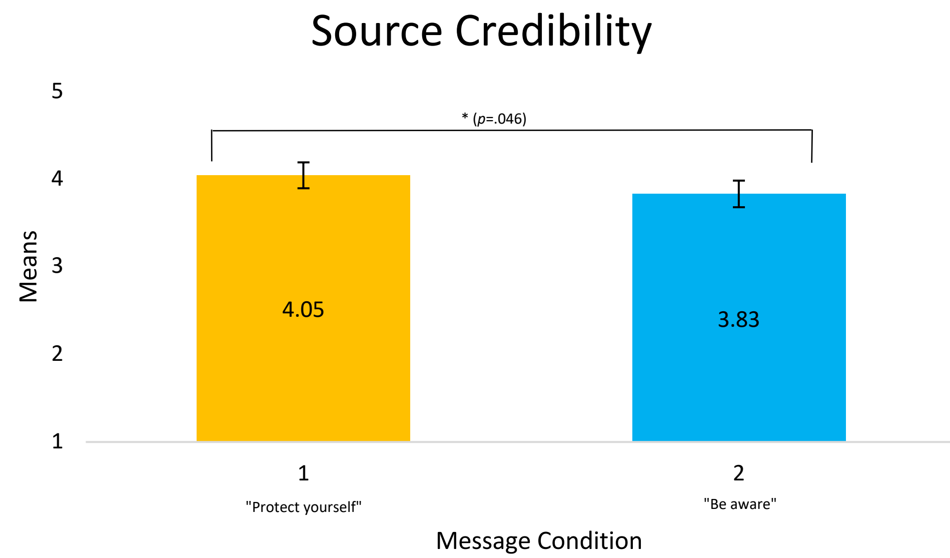


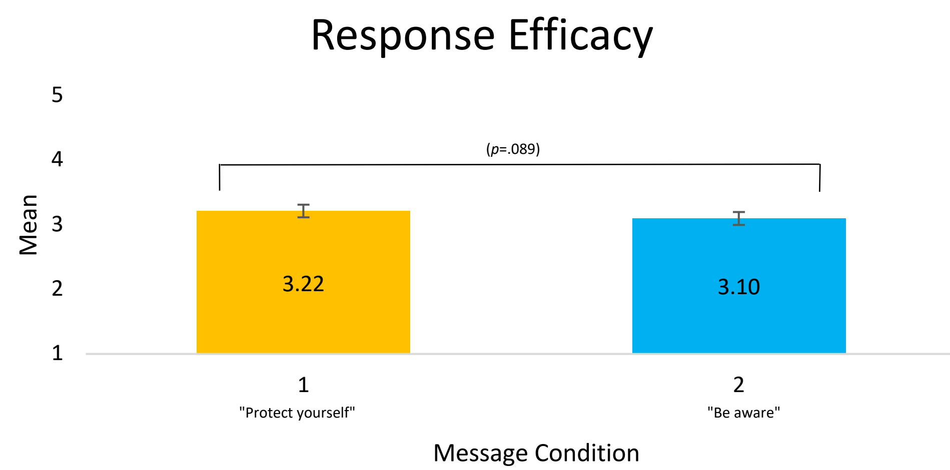
Experiment 4

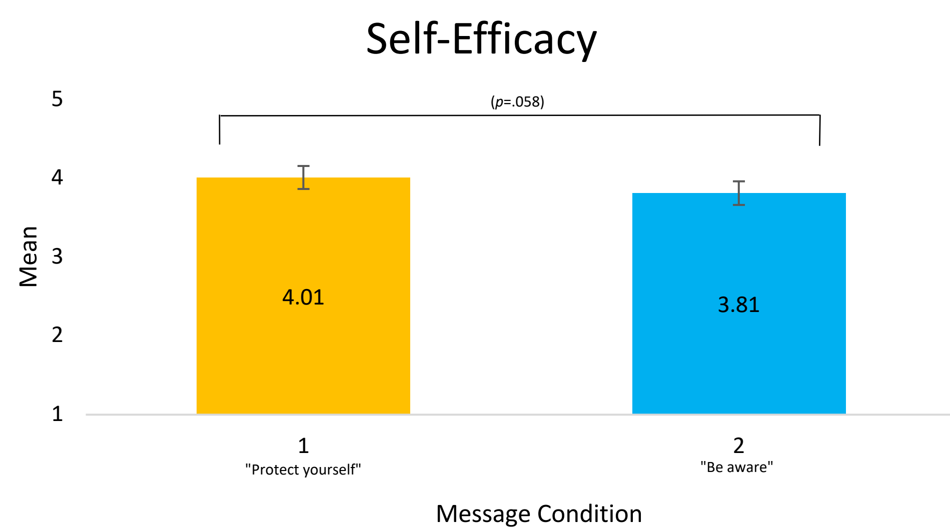




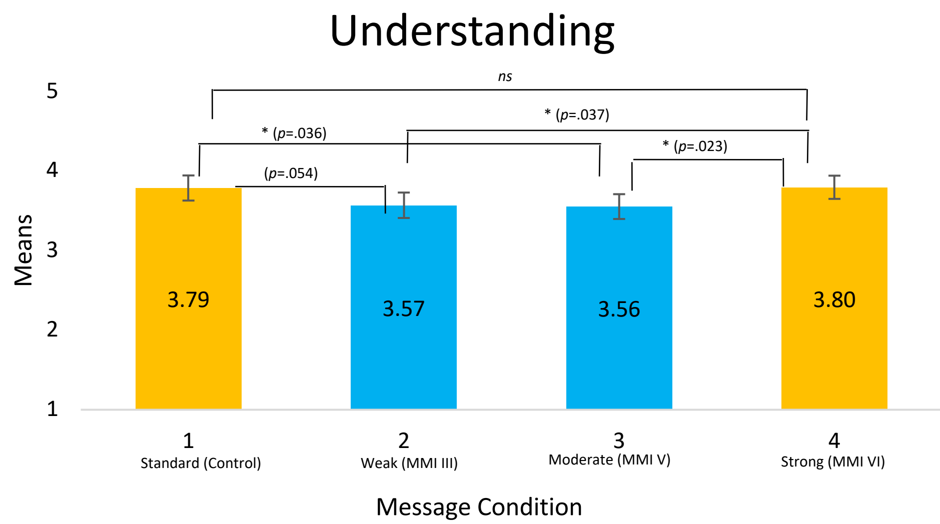


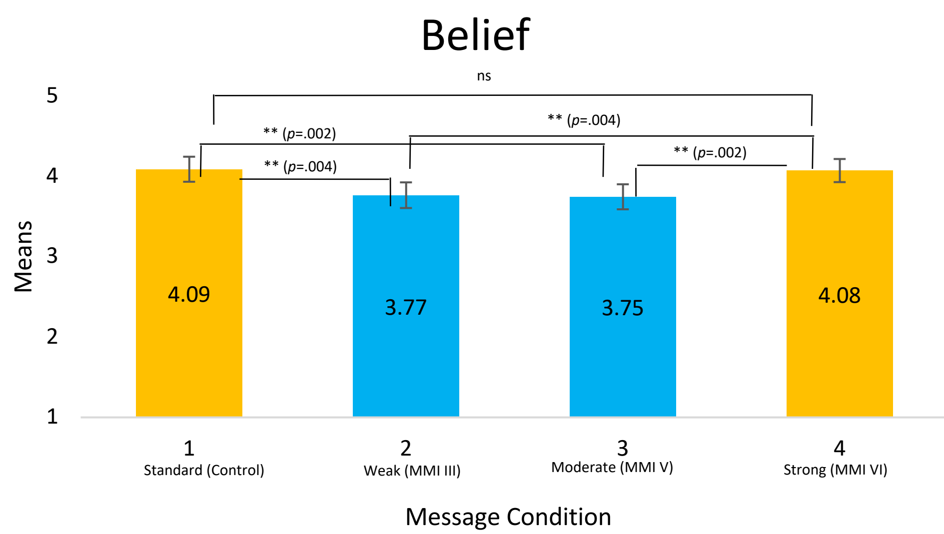

Source Credibility
Means
5
4
3
2
1
* (p=.046)
4.05
3.83
1
"Protect yourself"
2
"Be aware"
Message Condition

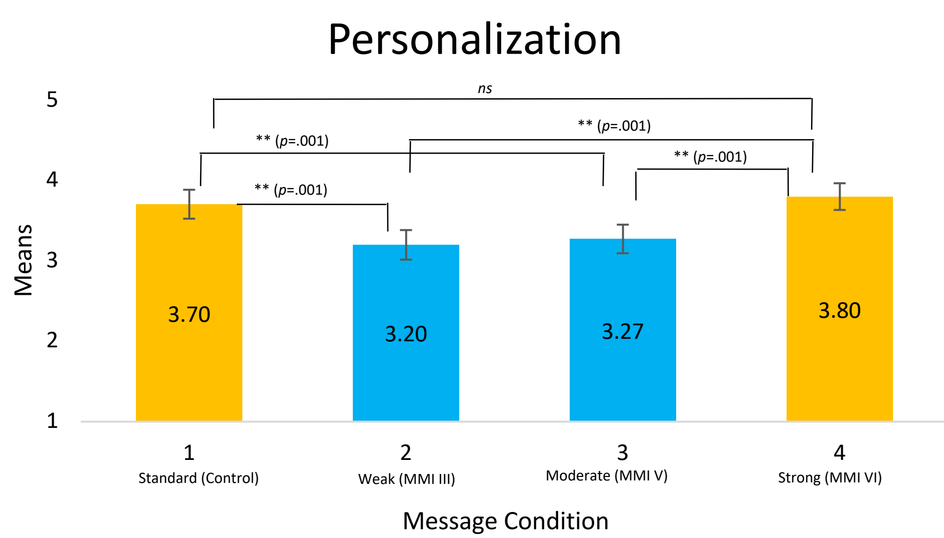

Response Efficacy
Mean
5
4
3
2
1
(p=.089)
3.22
3.10
1
"Protect yourself"
2
"Be aware"
Message Condition

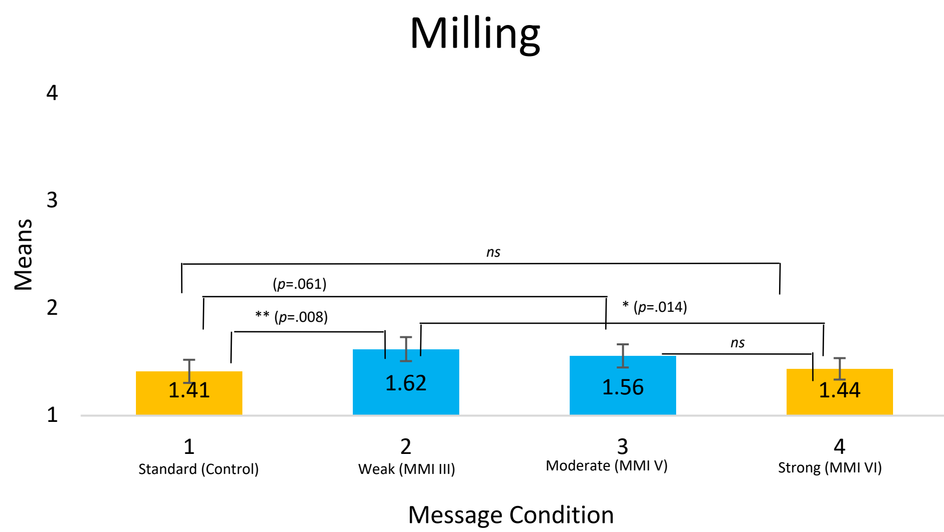

Self-Efficacy
Mean
5
4
3
2
1
(p=.058)
4.01
3.81
1
"Protect yourself"
2
"Be aware"
Message Condition

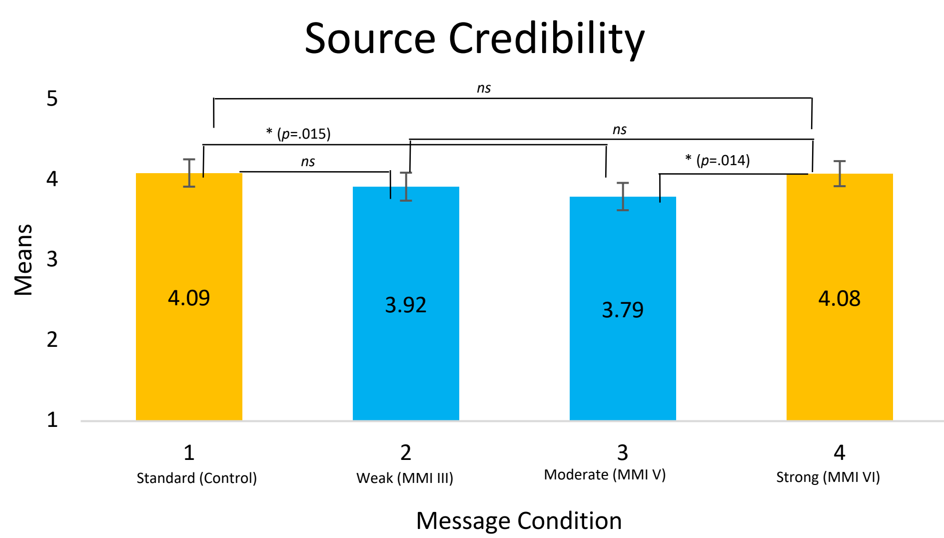
Experiment 5











Experiment 6

NA