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The Effects of Earthquake Experience on Intentions to Respond to Earthquake Early Warnings

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Warning systems are essential for providing people with information so they can take protective action in response to perils. Systems need to be human-centered, which requires an understanding of the context within which humans operate. Therefore, our research sought to understand the human context for Earthquake Early Warning (EEW) in Aotearoa New Zealand, a location where no comprehensive EEW system existed in 2019 when we did this study. We undertook a survey of people's previous experiences of earthquakes, their perceptions of the usefulness of a hypothetical EEW system, and their intended responses to a potential warning (for example, Drop, Cover, Hold (DCH), staying still, performing safety actions). Results showed little difference in perceived usefulness of an EEW system between those with and without earthquake experience, except for a weak relationship between perceived usefulness and if a respondent's family or friends had previously experienced injury, damage or loss from an earthquake. Previous earthquake experience was, however, associated with various intended responses to a warning. The more direct, or personally relevant a person's experiences were, the more likely they were to intend to take a useful action on receipt of an EEW. Again, the type of experience which showed the largest difference was having had a family member or friend experience injury, damage or loss. Experience of participation in training, exercises or drills did not seem to prompt the correct intended actions for earthquake warnings; however, given the hypothetical nature of the study, it is possible people did not associate their participation in drills, for example, with a potential action that could be taken on receipt of an EEW. Our analysis of regional differences highlighted that intentions to mentally prepare on receipt of a warning were significantly higher for Canterbury region participants, most likely related to strong shaking and subsequent impacts experienced during the 2010–11 Canterbury Earthquake Sequence. Our research reinforces that previous experience can influence earthquake-related perceptions and behaviors, but in different ways depending on the context. Public communication and interventions for EEW could take into consideration different levels and types of experiences of the audience for greater success in response.

Keywords: earthquakes, Earthquake Early Warning (EEW), experience, perceptions, protective action

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INTRODUCTION

Warning systems represent a critical element of the communication landscape and are aimed at providing information so people can take protective responses to various perils. While many warning systems tend to focus on the technical capabilities of providing warning information, warning systems in fact comprise a number of elements, all of which are needed for effective responses to occur. Kelman and Glantz (2014) summarize these aspects as risk knowledge, monitoring and warning, dissemination and communication and response capability. Basher (2006) and Harrison et al. (2020) argue that given effective responses are a key outcome of a warning system, a people-centered approach should be taken to warnings. This is reflected in the United Nations Office for Disaster Risk Reduction (UNDRR)[1] definition of an early warning system which states it is: "The set of capacities needed to generate and disseminate timely and meaningful warning information to enable individuals, communities and organizations threatened by a hazard to prepare and to act appropriately and in sufficient time to reduce the possibility of harm or loss" (United Nations International Strategy for Disaster Risk Reduction (UNDRR), 2009, p. 12). Consequently, in developing an effective warning system it is important to understand the environmental, social and experiential context in which humans are located, to be able to identify how they might best receive, interpret, and respond to warnings, and then utilize that in warning system development (McBride et al., 2022).

Warnings can be disseminated and received for a wide range of perils, including natural hazards such as severe weather, flooding, volcanoes, tsunami and landslides. With the progression of science and technology, *earthquake* early warnings (EEW) are now also delivered to citizens in a number of countries including Japan, Taiwan, Mexico, South Korea, the West Coast of the United States of America (USA), Sichuan China and Peru (Allen and Melgar, 2019; Fallou et al., 2022; McBride et al., 2022), among others. An EEW comprises advanced notification of earthquake shaking, delivered by a device such as a mobile phone or stand-alone alerting device, or *via* channels such as the media. The ability to send such a notification is dependent upon detecting an earthquake that has already occurred (e.g., by detecting the earthquake with sensors at its source or *via* P-waves) and sending out a warning in advance of the arrival of shaking from S-waves (Given et al., 2018).

Most warnings are usually only issued for locations anticipated to receive strong shaking, as this is where damage, injury, and potentially death may occur (Allen et al., 2018; Allen and Melgar, 2019; Allen and Stogaitis, 2022). Notification may be received anywhere from a few seconds to minutes before shaking ensues; however, most warnings will be in the range of seconds to tens of seconds, rather than minutes (Minson et al., 2018). In some instances, if a person is located very close to the epicenter of an earthquake, there may not be time for a warning and the notification might arrive after shaking has started. In addition, delays to delivery of alerts including technological latencies in alerting channels, like cell broadcast or similar systems, will further delay when an alert can be delivered (Prasanna et al., 2022).

Upon receipt of a warning notification, citizens have the opportunity to take action to protect themselves from the incoming shaking. The actions that people might take vary from country to country. In the United States of America, for example, people are usually advised to protect themselves by performing Drop, Cover and Hold On (DCHO) when shaking occurs (Jones and Benthien, 2011; McBride et al., 2022), with additional advice provided on other protective actions for specific circumstances such as when driving (Washington State Emergency Management Division, 2017). Similar advice is promoted in places like Japan and Aotearoa New Zealand, where the message has been simplified to Drop, Cover, Hold (DCH) (McBride et al., 2019; Vinnell et al., 2020). This advice is relevant because most buildings in such countries are expected to perform adequately in an earthquake. However, in other countries where construction is not as sound (e.g., Mexico) advice focusses on evacuating buildings on receipt of an EEW (Santos-Reyes, 2020; McBride et al., 2022). Japan, which has had an official EEW system operating since 2007 (Fujinawa and Noda, 2013), also provides advice on a variety of other safety actions to take on receipt of a warning (e.g., stopping elevators and getting off at the nearest floor; Japan Meteorological Agency, 2019).

Influences on People's Ability to Respond to EEWs

People's ability to respond to EEWs may be confounded by a range of factors. In the first instance, timing can be an issue. Where the time between a warning and the commencement of shaking is very short (i.e., a few seconds) citizens might only be able to stop and stay still or DCH (Nakayachi et al., 2019; Becker et al., 2020a). As warning timeframes increase, the opportunity for taking further safety actions or evacuating a building is possible. However, this opportunity also creates the added possibility of injuries if people are still moving as shaking commences (Shoaf et al., 1998; Johnston et al., 2014; Horspool et al., 2020). Given EEW timeframes are often so short (e.g., see Becker et al., 2020b for Aotearoa New Zealand modeling), consideration about what actions to take needs to occur well in advance of an earthquake, and is best achieved through education programmes and practice of drills (Vinnell et al., 2020). Arguably, EEW struggles to meet the definition from the United Nations International Strategy for Disaster Risk Reduction (UNDRR) (2009), with "sufficient time to reduce the possibility of harm or loss" being at issue here, as EEW may not provide this given its technological and physical limitations. Even with faster alerting channels and improved technology, there may always be some physical limitations to the system, such as a late alert zone, where the earthquake's epicenter is too close to an area for it to be categorized and calculated by algorithms, let alone sent out *via* various alerting channels before shaking arrives (Minson et al., 2019; McBride et al., 2020).

Second, citizens' desire and ability to act upon an EEW is influenced by a range of cognitive, social, and affective factors.

[1] Previously known as the United Nations Office for Disaster Risk Reduction (UNISDR).

Some of these aspects can directly influence people's responses to warnings, while others have a more indirect influence on the process. People's previous experiences of earthquakes are a part of this mix. Experience can be described in many different ways, an issue that has been highlighted and which makes it difficult to draw comparisons between studies (Becker et al., 2017). For this paper, we use the terms direct, indirect, vicarious, and life experience as defined by Becker et al. (2017). In terms of earthquakes, direct experience includes physically feeling strong shaking, or being impacted through injury or loss. Even direct earthquake experiences are highly variable, by frequency, intensity and context. Indirect experience includes being exposed indirectly to an event (e.g., having travel or employment disrupted) or observing a local event. Vicarious experience includes occasions where one might interact with friends and family with regard to a disaster, or observe a disaster in the media, rather than a disaster having a direct or indirect impact upon themselves. Vicarious experience can also extend to educational efforts including drills and exercises, which develop procedural knowledge as to what protective actions to take (Johnson et al., 2014; McBride et al., 2019), or when people are exposed to disaster scenarios but do not live through those disasters directly. Life experience is a fourth type of relevant experience where people might refer back to other adverse events or situations in their lives (e.g., experiencing a health issue, a car or work accident, power outages, crime, war) in understanding how they might respond to an earthquake (Norris, 1997; Paton et al., 2000; Becker et al., 2017).

The Influence of Previous Experience on Responses to Earthquake Threats

Previous research highlights the diverse ways in which experience can affect people's responses to earthquakes. Given the relatively recent emergence of technology that has made EEW more accessible for use, most research has been completed in an earthquake preparedness context, as opposed to a warnings context. Some researchers have found that earthquake experience can be a driver of preparedness activity (e.g., Kiecolt and Nigg, 1982; Lehman and Taylor, 1987; Mileti and Fitzpatrick, 1992; Mileti and Darlington, 1997; Lindell and Perry, 2000; Tanaka, 2005; Dunn et al., 2016; Becker et al., 2017; Vinnell et al., 2017; Doyle et al., 2018), while others have found the opposite (e.g., Mulilis et al., 1990; Farley, 1998; Lindell and Prater, 2002; Basolo et al., 2009; Bourque et al., 2012; Lindell, 2013; Shapira et al., 2018).

The nature of people's experience appears to be key to whether previous experience will enhance preparedness or not. Experiences such as being directly impacted by an earthquake (e.g., experiencing damage, loss or injury; Jackson, 1981; Turner et al., 1986; Blanchard-Boehm, 1998; Lindell and Prater, 2000; Nguyen et al., 2006); being indirectly impacted (e.g., evacuating following an earthquake, participating in rescues; Becker et al., 2017; Doyle et al., 2018), or being vicariously affected in a more personal way (e.g., experience of loss by a family member; Turner et al., 1986) have been identified as influential in motivating people to prepare for future earthquakes. However, as Lindell (2013) highlights, even these types of experiences have their own unique nuances which influence decisions about whether to prepare or not, and how to prepare.

Additionally, researchers have found various mediating factors that influence the experience-preparedness process. These include such aspects as risk perception (Solberg et al., 2010; Bourque et al., 2012; Bourque, 2013; McClure et al., 2015; Dunn et al., 2016), biases stemming from certain perceptions such as optimism and normalization biases (Weinstein, 1989a; Mileti and O'Brien, 1992; Helweg-Larsen, 1999; Spittal et al., 2005; Shapira et al., 2018), levels of concern, fear or anxiety (Dooley et al., 1992; Rüstemli and Karanci, 1999; Karanci and Aksit, 2000; Siegel et al., 2003; Heller et al., 2005; Dunn et al., 2016; Paton and Buergelt, 2019) and people's ability for personal control (Rüstemli and Karanci, 1999). Research in Aotearoa New Zealand particularly has shown that potential barriers to preparation behavior such as cost or logistics are less influential than cognitive barriers (McClure et al., 2015; Vinnell et al., 2021).

Many of the factors and biases outlined above are evolved protective mechanisms to help individuals cope in response to an overwhelming number of risks that we encounter in our daily lives. Such risks can range from the lower likelihood high impact events such as an earthquake through to higher likelihood less widely impacting events such as car accidents. Biases work to reduce feelings of fear about risks; for example, optimism biases involve an individual believing they are less likely to suffer negative consequences than other people like them (Weinstein, 1989b), despite this being probabilistically flawed. Normalization bias involves the individual believing that all future events (e.g., earthquakes) will be similar to all past events that they have experienced (Mileti and O'Brien, 1992; Mileti and DeRouen Darlington, 1995; Johnston et al., 1999). Therefore, if a person feels a previous earthquake was not bad in terms of shaking or impacts, they might consider future earthquake risk to be low and optimistically not bother preparing, or not intend responding to an EEW. These psychological mechanisms are useful as they allow individuals to function in the face of a multitude of risks but pose a challenge which must be overcome when trying to motivate preparedness. Our understanding of how these factors operate is therefore important to unpacking how experience might influence preparedness, and potentially future responses to EEW.

Several theories have been developed to explain and predict people's behavior in hazard contexts, including in response to warnings, including the Protective Action Decision Model (PADM) (Lindell and Perry, 2012); Protection Motivation Theory (PMT) (Tanner et al., 1989), and Community Engagement Theory (CET) (Paton, 2013). Theories from other areas of behavioral sciences have also been applied in the hazard context, including Emergent Norm Theory (ENT) (Wood et al., 2017) and the Theory of Planned Behavior (TPB) (Vinnell et al., 2021). These models propose a large number of factors which can influence both people's preparation behavior and response behavior, including environmental and social cues; information about the peril/warning itself; exposure to that information; perceptions about the threat, actions, and what others think; and factors related to the current situation. Such inputs will determine an eventual response such as undertaking protective action, conducting an information search, or an emotional response. Sometimes people will also reach a conclusion that they will do nothing.

While much research has focussed on warnings in the context of other perils (e.g., tornadoes, hurricanes, volcanoes), there has been very limited work on responses to earthquake early warning, likely due to the relatively recent nature of emerging technologies to support widespread warning responses across different countries. Studies that have been conducted have focussed on perceptions of EEW and either intended or actual responses to earthquake warnings. The following outlines these studies.

Prior Studies on EEW Perceptions, Experiences and Responses

First, it has been important to understand how useful people perceive EEWs to be. We know from the PADM model and from other studies, that perceptions about preparedness (in this case a warning system) and protective actions are influential in people's decision-making about whether to undertake actions or not (Lindell and Perry, 2012; Johnston et al., 2013; Becker et al., 2015; Vinnell et al., 2017). If an EEW system is perceived as useful, and the warnings actionable, then citizens may be more likely to use it. Results from research on the perceptions of EEW usefulness have been mixed, however, depending on the context. For hypothetical EEW scenarios, citizens have expressed strong support for EEW utility (Dunn et al., 2016; Becker et al., 2020a,b). In real warning situations, some researchers have found that people do consider warnings useful, even when issues arise with warning systems, such as receiving false alerts or late alerts after shaking has occurred (Nakayachi et al., 2019; Fallou et al., 2022). However, other research by Santos-Reyes (2020) has found that perceptions of warning systems' usefulness can fall following a devastating earthquake (i.e., a Magnitude 7.1 earthquake in Mexico on 10 Sept 2017 when warnings were not provided in enough time before shaking for people to act). Given the 2017 earthquake in Mexico caused damage, injury and deaths, it was perhaps the severe impacts from this experience that influenced people's subsequent perceptions about EEW's utility, and possibly also recalibrated people's understanding of its true effectiveness.

Second, research on citizens' actual and intended responses to alerts have also had mixed conclusions. Studies from Japan suggest citizens are more likely to mentally prepare and stop and stay still on receipt of a warning, rather than take a specific protective action (Nakayachi et al., 2019). Reasons for the Japanese population not taking specific protective actions on receipt of an alert appear to relate to previous experience, where prior warnings have not resulted in strong shaking, leading to lower risk perception and optimism that strong shaking will not follow warnings in future. Data from a Peru survey highlight a similar lack of protective action, whereby participants reported that on receipt of an alert, they more often warned people nearby or waited for shaking to begin (Fallou et al., 2022). These studies show that having previous experience of EEWs does not necessarily translate into people taking protective action for alerts, for various reasons. However, when surveying *intended* responses of citizens from other countries without operational EEW systems (e.g., United States of America prior to EEW roll-out on the West Coast, and Aotearoa New Zealand), people were more likely to *intend* to take protective actions such as DCH (Dunn et al., 2016; Becker et al., 2020a), in comparison with Japan and Peru. Whether these intentions are accurate or not is questionable (Becker et al., 2020a). As an example, Dunn et al. (2016) found in their survey that 53% suggested they would DCHO, while only 20% had actually done so for an earthquake. Only future research will help us understand whether intentions predict actions in an EEW context.

Additionally, from an experience perspective, Dunn et al. (2016) looked at citizens' prior experiences of earthquakes and perceptions of EEW in a "willingness to pay" for warnings context (i.e., willingness to pay for an earthquake early alert app.). In their survey, respondents with previous earthquake experience had a higher familiarity with the concept of EEW, and were slightly more likely to consider EEW effective, in that they believed they could better protect themselves from earthquake risks. However, respondents with experience of an actual earthquake also had less willingness to pay for an EEW app., possibly due to the fact that most of their previous experiences only related to moderate shaking levels which were of limited concern. People who had vicarious experience of watching the "San Andreas" movie expressed more willingness to pay. The Dunn et al. (2016) survey highlighted some of the influences of previous earthquake experience on EEW, namely people's perception that EEW could provide them with a better outcome (i.e., positive outcome expectancy), and that different types of experience can be influential on the process (i.e., in this case, direct vs. vicarious experience), but in different ways.

The influence of previous experience is difficult to understand in the context of earthquake preparedness, let alone in a warning context. Given limited behavioral research on EEW, the effects of experience on earthquake warning response behavior is untested. Therefore, we undertook research to attempt to advance our understanding on this topic. Particularly, we were interested in understanding whether previous earthquake experience might influence both people's perceptions of EEW and their responses upon receiving an alert.

To do this we undertook a survey in 2019 in Aotearoa New Zealand. Given Aotearoa New Zealand had no comprehensive EEW system in 2019 (Prasanna et al., 2022), the survey focussed on a hypothetical EEW context. Within the survey, we asked a range of questions about preferred EEW system attributes and anticipated responses to EEW, of which the general findings are reported in Becker et al. (2020a). We also asked about people's experiences of previous earthquakes from a direct, indirect and vicarious experience perspective. We were interested in finding out what effect such experiences had on perceived usefulness of EEW and intended responses to warnings. This paper discusses key findings from the survey in relation to earthquake experience and EEW.

MATERIALS AND METHODS

Our survey contained 20 questions, most of which were quantitative single response, multiple response and Likert or Likert-type scale questions (Joshi et al., 2015) (18 questions), with the others being qualitative free response questions (2 questions). The survey covered aspects of previous earthquake experience, anticipated responses to a hypothetical EEW scenario, perceived usefulness of EEWs, preferred attributes of an EEW system, earthquake preparedness [including participation in workplace or volunteer training, emergency management exercises in general, and targeted drills such as the ShakeOut earthquake drill (Jones and Benthien, 2011)] and demographics. Aside from the provision of the hypothetical scenario, no additional information was given about EEWs, and people's responses to the questions were unprompted. More information about the survey is available in Becker et al. (2020a). Only the questions relevant to the analyses reported in this paper are presented here. Under Massey University human ethics procedures, the survey was deemed low risk, and received an Ethics Notification Number of 4000019302.

The survey was uploaded online into the SurveyMonkey software programme (SurveyMonkey, 1999–2022) and was promoted to Aotearoa New Zealand citizens *via* a press release that resulted in press articles in the online newspaper "Stuff" and a radio interview with Newstalk ZB. Additionally the survey was promoted on social media though Facebook and Twitter *via* the following sources: GeoNet, QuakeCoRE, Resilience to Nature's Challenges National Science Challenge, East Coast Life at the Boundary, Alpine Fault 8, and the Joint Center for Disaster Research. We opened the survey for participation on 22 March 2019 and closed it on 30 April 2019. During this time period no significant earthquake events occurred. A total of 3,084 self-selected responses were received from citizens across Aotearoa New Zealand as per a convenience sample. Participants were of average age distribution (when compared to New Zealand census data (StatsNZ, 2018; sample range 18–80+, 47% between 30 and 49 years old), but more likely than average to be female (65%) and consider themselves of New Zealand (40%)/New Zealand European (46%) ethnicity. Males (33%) and other ethnicities such as Māori (4%) were under-represented in the data. Nearly 60% of participants reported that they already knew what Earthquake Early Warning was, prior to undertaking the survey. Further details about the survey method are presented in Becker et al. (2020a), along with frequency results and the Supplementary Data set for the full survey.

Previous Earthquake Experience

Participants were asked to indicate which, if any, previous experiences they had with earthquakes out of the following options:

1. I have personally felt an earthquake before.
2. I have felt strong shaking (i.e., MM6—where people and animals are alarmed, and many run outside. Walking steadily is difficult. Furniture and appliances may move on smooth surfaces, and objects fall from walls and shelves. Glassware and crockery break. Slight non-structural damage to buildings may occur).
3. I have experienced personal injury, damage or loss from an earthquake.
4. I have had family or friends injured, or experience damage or loss from an earthquake.
5. I have observed local earthquake damage or loss (e.g., in my neighborhood or city).
6. I have observed earthquake damage or loss *via* the media (e.g., television, internet).

Intentions

Participants reported how likely they would be to take particular actions after receiving a warning for a hypothetical scenario. The scenario was developed to be as similar as possible to real alerts experienced in Japan following the Gunma and Chiba earthquakes in 2018 (see Nakayachi et al., 2019). The hypothetical scenario involved participants' receipt of a mobile phone alert at 8.30 pm on a Saturday evening which said, "Earthquake Early Warning. Strong shaking expected soon". Participants indicated whether, on receipt of this alert, they would on a 5-point scale be "Extremely unlikely" to "Extremely likely" to:

1. Do nothing/undertake no actions.
2. Look for further earthquake information about the warning (e.g., check GeoNet, TV, radio or mobile phone or talk to other people).
3. Tell other people the earthquake is coming.
4. Stop, and stay still, awaiting the shaking on the spot.
5. Mentally prepare myself for the shaking.
6. Take specific behaviors to protect myself on the spot (e.g., Drop, Cover, Hold; hold on to something; protect head; take cover under the table etc.).
7. Move nearby to where I think it is safe.
8. Go outside.
9. Undertake safety actions (e.g., secure furniture, secure a potentially dangerous piece of equipment, turn something off (e.g., gas fire), open the door to secure the way out, put on clothes or shoes).
10. Help others, or act to protect others (e.g., children, other family, friends, workmates).
11. Slow down, pull over and stop car.

Perceptions of Usefulness

Participants responded to the question "How useful do you think an EEW would be for you?" with a 4-point scale from "Useless" to "Useful".

Previous Earthquake-Related Behavior

Participants indicated which behaviors they had undertaken to prepare for an earthquake. Of interest in this paper were the following two behaviors:

1. I have participated in training or exercises, so I can better respond to emergencies.
2. I have practiced responding to an earthquake drill (e.g., Drop, Cover, Hold as part of ShakeOut or self-organized drills).

Research Questions

To understand how previous earthquake experience might influence responses to EEW we developed three primary research questions and undertook statistical tests on the specific questions from the survey described above. We describe each below.

Research Question 1: Do EEW Perceptions and Intentions Differ Between Those With and Without Prior Earthquake Experience?

RQ1a: We tested whether perceptions of the usefulness of EEW differed between those with and without prior earthquake experience using a series of six independent samples *t*-tests. In all tests the dependent variable was perceived usefulness of EEW. Participants were split into groups depending on whether they indicated they had or did not have a particular type of earthquake experience.

RQ1b: Similarly, we tested whether the actions participants intended to take differed between those with and without prior experience using independent samples *t*-tests. Mean intentions to undertake a particular action (dependent variable) were compared between those participants with and without each specific type of experience (grouping variable).

Research Question 2: Is Preparedness, Particularly Participation in Training, Exercises or Drills, Related to People's Intended Actions for an EEW?

RQ2a: We tested whether mean intentions to undertake each action in response to an EEW (dependent variable) differed between those who had participated in training or practiced emergency management exercises and those who had not (grouping variable) using a series of independent samples *t*-tests.

RQ2b: Similar to RQ2b, we tested whether mean intentions to undertake each action differed between those who had practiced earthquake drills and those who had not using a series of independent samples *t*-tests.

Research Question 3: Do Intentions to Undertake Particular Actions in Response to an EEW Differ Between Regions of Aotearoa New Zealand Which Have Experienced More Earthquakes?

For the purposes of locational analysis, we grouped responses from certain regional areas together into Auckland (n = 223), Canterbury ($n = 729$), Hawke's Bay/Gisborne (Tairāwhiti) combined ($n = 147$); Wellington ($n = 799$); and Otago/Southland combined (n = 157). Location in this way acts as a proxy for earthquake experience, as only two regions had experienced strong shaking from earthquakes in the previous 10 years; notably, the Canterbury earthquakes in 2010–11 that affected wider Canterbury and the 2016 Kaikoura earthquake for which the Canterbury and Wellington regions experienced strong shaking (**Figure 1**).

RQ3: Mean intention scores for each particular action were compared between the five locations using a series of one-way Analyses of Variance (ANOVAs).

Limitations

Some types of earthquake experience were quite widely reported; for example, 93% of participants had felt an earthquake before and 87% had observed earthquake damage or loss through the media. However, the large sample size of this study means that even in these instances there were at least 200 participants *without* this experience, making group comparisons relatively robust. A further limitation of this study is the use of hypothetical situations and the measurement of intentions rather than behavior. While intentions do not perfectly predict actual behavior, they are seen as one of the best factors to approximate behavior when behavior cannot be measured (Armitage et al., 2013). Additionally people's ability to assess the usefulness of a system might vary in the context of having no system, vs. their experiences with an actual operating system. Given the unpredictability of earthquakes, and the fact that this research was part of a project to scope the viability and enthusiasm for an EEW system in Aotearoa New Zealand, assessing actual responses was not feasible. Finally, this study examined direct associations between specific types of earthquake experience and intentions to respond to an EEW rather than considering the interactive nature of disaster experience (Becker et al., 2017).

RESULTS

RQ1a: Does Prior Experience of Earthquakes Influence Perceptions of Usefulness of EEW?

Those who have had family or friends injured, or experienced damage or loss from an earthquake, saw EEW as significantly more useful (Mean [M] = 1.25, Standard Deviation [SD] = 0.53) than those who have not (M = 1.29, SD = 0.57), independent samples *t*-test result: $t_{(2451.45)} = 1.99$, significance level $p < 0.05$, Cohen's effect size $d = 0.08$. This is a weak effect (indicated by the relatively small d value), and all other tests for difference in means in perceived usefulness between groups with different types of experience and those without were non-significant (p-values from 0.36 to 0.92). Overall, these findings suggest that prior earthquake experience does not influence perceptions of the usefulness of EEW.

RQ1b: Does Prior Experience of Earthquakes Influence Intended Actions?

Those who have personally felt an earthquake before had marginally weaker intentions to do nothing (M = 2.10, SD = 1.42) than those who had not felt an earthquake (M = 2.30, SD = 1.53), $t_{(206.34)} = 1.72$, $p = 0.09$, $d = 0.24$. Participants were also less likely to go outside if they had personally felt an earthquake before (M = 2.67, SD = 1.36) than if they had not (M = 2.30, SD = 1.34), $t_{(2615)} = 2.70$, $p < 0.01$, $d = 0.11$. Finally, participants were less likely to slow down, pull over, and stop their car if they had felt an earthquake before (M = 3.92, SD = 1.19) than if they had not (M = 4.08, SD = 1.07), $t_{(210.36)} = 2.00$, $p < 0.05$, $d = 0.28$. There was no significant difference in intentions for any other actions between those who had and those who had not personally felt an earthquake (p-values from 0.14 to 0.96).

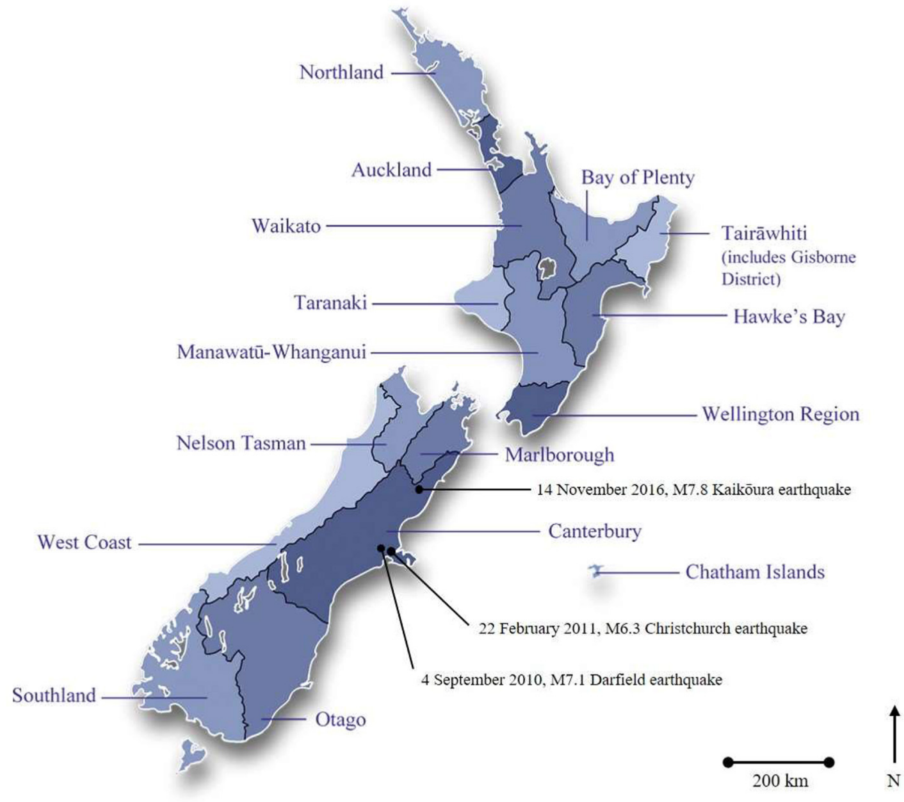

FIGURE 1 | Map of Aotearoa New Zealand showing regional areas as defined by Civil Defence Emergency Management boundaries (National Emergency Management Agency, 2013), the locations of the Darfield and Christchurch earthquakes (from the 2010–11 Canterbury Earthquake Sequence) and the location of the 2016 Kaikoura earthquake (GNS Science, 2016).

TABLE 1 | Results of independent samples *t*-tests comparing mean intentions scores for a range of actions between those who have and have not felt strong shaking.

	Felt strong shaking		Not felt		*t*	*df*	*p*	*d*
	M	*SD*	*M*	*SD*				
Look for more information	3.68	1.38	3.81	1.31	2.20	1304.27*	0.028	0.122
Stop, stay still, wait for shaking	2.81	1.33	2.69	1.27	2.07	2,630	0.039	0.081
Mentally prepare for shaking	4.42	0.84	4.33	0.90	2.43	2,687	0.015	0.094
Go outside	2.66	1.36	2.79	1.36	2.08	2,615	0.037	0.081
Slow down, pull over and stop car	3.96	1.18	3.86	1.20	1.89	2,598	0.059	0.074

*Scales ranged from 1 to 5, with larger values indicating stronger intentions. *This number is not an integer as the data did not pass Levene's test of sphericity so the Greenhouse-Geisser correction was applied. Source data can be found in Becker et al. (2020a).*

Those who had felt strong shaking were less likely to intend to look for further information and marginally less likely to slow down, pull over and stop their car than those who had not felt strong shaking (**Table 1**). Further, those who had felt strong shaking were more likely to intend to stop, stay still and wait for shaking and to mentally prepare themselves than those who did not have prior experience of strong shaking. There were no other significant differences in intentions for the remaining actions (p-values from 0.314 to 0.944).

Similar to the previous findings, participants who had experienced personal injury, damage, or loss from an earthquake were more likely to intend to mentally prepare themselves for shaking ($M = 4.46$, $SD = 0.82$) than those who had not ($M = 4.37$, $SD = 0.87$), $t_{(2,687)} = 2.64$, $p < 0.01$, $d = 0.10$ and to slow down, pull over and stop their car ($M = 4.06$, $SD = 1.15$) than those who had not ($M = 3.87$, $SD = 1.19$), $t_{(1560.69)} = 3.77$, $p < 0.01$, $d = 0.19$. Further, those who had personally experienced injury, loss, or damage had stronger intentions to help or act to

TABLE 2 | Results of independent samples *t*-tests comparing mean intentions scores for a range of actions between those who have and have not had family or friends injured, or experienced damage or loss from an earthquake.

	Family or friends have experienced injury, damage or loss		Family or friends have not experienced injury, damage or loss		*t*	*df*	*p*	*d*
	M	***SD***	***M***	***SD***				
Do nothing	2.05	1.42	2.19	1.43	2.47	2,577	0.014	0.097
Tell other people	4.29	1.02	4.20	1.06	2.36	2,670	0.018	0.091
Mentally prepare for shaking	4.44	0.84	4.35	0.87	2.86	2,687	0.004	0.110
Move nearby to safety	4.44	0.87	4.38	0.88	1.98	2,676	0.048	0.077
Go outside	2.65	1.36	2.75	1.37	1.75	2,615	0.080	0.068
Undertake safety actions	3.77	1.22	3.66	1.24	2.24	2,676	0.025	0.087
Help or act to protect others	4.46	0.84	4.35	0.89	3.24	2,439.87	0.001	0.131
Slow down, pull over and stop car	4.00	1.15	3.84	1.22	3.33	2,379.01	0.001	0.137

Source data can be found in Becker et al. (2020a).

TABLE 3 | Results of independent samples *t*-tests comparing mean intentions scores for a range of actions between those who have and have not observed earthquake damage or loss *via* the media.

	Observed earthquake damage or loss *via* the media		Have not observed earthquake damage or loss *via* the media		*t*	*df*	*p*	*d*
	M	***SD***	***M***	***SD***				
Do nothing	2.06	1.41	2.49	1.50	4.75	386.86	0.000	0.483
Look for more information	3.69	1.37	3.89	1.26	2.61	432.51	0.009	0.251
Stop, stay still, wait for shaking	2.74	1.31	3.00	1.37	3.22	2,630	0.001	0.126
Go outside	2.67	1.36	2.88	1.36	2.62	2,615	0.009	0.103

Source data can be found in Becker et al. (2020a).

protect others ($M = 4.47$, $SD = 0.86$) than those who had not ($M = 4.39$, $SD = 0.86$), $t_{(2,677)} = 2.39$, $p < 0.05$, $d = 0.09$.

Interestingly, having a family member or friend experience injury, damage, or loss in an earthquake seemed to have more of an effect on intentions to act when given a warning than personal experience. Those who have had a family member or friend suffer injury, damage, or loss were more likely to intend to tell other people, mentally prepare, move nearby to somewhere safe, undertake safety actions such as turning off gas, help or act to protect others, and to slow down and pull their car over if driving (**Table 2**). Further, participants with this type of experience were less likely to intend to do nothing and marginally less likely to intend to go outside than those without this experience. However, there was no difference between the two groups on intentions to look for further information ($p = 0.862$), to stop and wait for the shaking ($p = 0.126$), or to take specific actions such as Drop, Cover, and Hold ($p = 0.502$).

Those participants who had observed local earthquake damage were less likely to intend to do nothing ($M = 2.05$, $SD = 1.42$) than those who had not ($M = 2.24$, $SD = 1.43$), $t_{(1775.70)} = 3.26$, $p < 0.01$, $d = 0.155$, but were also less likely to look for further information ($M = 3.66$, $SD = 1.39$; $M = 3.81$, $SD = 1.30$), $t_{(1964.59)} = 2.72$, $p < 0.01$, $d = 0.123$, and were less likely to intend to go outside ($M = 2.63$, $SD = 1.36$; $M = 2.82$, $SD = 1.36$), $t_{(2,615)} = 3.35$, $p < 0.01$, $d = 0.131$. Intentions to carry out the remaining actions did not significantly differ between those who had and those who had not observed local earthquake damage (p-values from 0.113 to 0.775).

Those who had observed earthquake damage or loss *via* the media indicated that they were less likely to do nothing when given a warning than those without this experience; however, all significant differences between two groups showed *lower* intentions to act among those with experience than those without, including the actions of looking for more information, stopping and staying still, and going outside (**Table 3**). All types of experience demonstrated significantly or marginally significantly lower intentions to go outside, suggesting that there might be a unique aspect to this behavior. However, it is surprising that despite a moderate effect in the direction of more action, the only significant differences suggested less action among those who had observed earthquake damage or loss *via* the media. All other tests were non-significant, with p-values ranging from 0.245 to 0.644.

TABLE 4 | Results of independent samples *t*-tests comparing mean intentions scores for a range of actions between those who have and have not practiced responding to an earthquake drill.

	Practiced		Not practiced		*t*	*df*	*p*	*d*
	M	*SD*	*M*	*SD*				
Do nothing	1.97	1.36	2.27	1.48	5.22	2507.98	0.000	0.209
Look for further information	3.65	1.38	3.78	1.34	2.47	2637.65	0.013	0.096
Stop, stay still, wait for shaking	2.73	1.30	2.83	1.33	1.98	2,630	0.048	0.077
Mentally prepare for shaking	4.43	0.86	4.37	0.85	1.68	2,687	0.093	0.065
Go outside	2.55	1.34	2.86	1.37	5.82	2,615	0.000	0.228
Undertake safety actions	3.67	1.25	3.79	1.20	2.41	2,670.46	0.016	0.093
Help or act to protect others	4.46	0.84	4.36	0.89	3.05	2,677	0.002	0.118

Source data can be found in Becker et al. (2020a).

RQ2a: Does Preparedness, Particularly Participation in Training or Exercises, Influence People's Intended Actions for an EEW?

Those who had participated in training or exercises to respond to emergencies reported weaker intentions to do nothing when given a warning ($M = 2.01$, $SD = 1.37$) than those who had not participated in training or exercises ($M = 2.15$, $SD = 1.44$), $t_{(968.86)} = 2.13$, $p < 0.05$, $d = 0.137$. However, the only significant difference for any of the action items was lower intentions to go outside among those who had participated in training ($M = 2.48$, $SD = 1.34$) than those who had not ($M = 2.76$, $SD = 1.37$), $t_{(2,615)} = 4.39$, $p < 0.01$, $d = 0.172$. However, those with training reported marginally higher intentions to mentally prepare themselves for shaking ($M = 4.45$, $SD = 0.82$) than those who had not ($M = 4.38$, $SD = 0.87$), $t_{(2,687)} = 1.71$, $p = 0.087$, $d = 0.066$, and marginally higher intentions to help or act to protect others ($M = 4.47$, $SD = 0.82$) than those who had not ($M = 4.40$, $SD = 0.87$), $t_{(2,677)} = 1.80$, $p = 0.072$, $d = 0.070$. All other tests were non-significant, with *p*-values ranging from 0.353 to 0.773.

RQ2b: Does Preparedness, Particularly Participation in Drills, Influence People's Intended Actions for an EEW?

Those who have practiced responding to an earthquake drill reported significantly lower intentions to do nothing than those who have not had such practice (**Table 4**). This finding suggests that those who have done drills are generally more likely to intend to take at least some action (as opposed to no action) than those who have not done a drill. The former group had significantly higher intentions to mentally prepare for shaking and to help or act to protect others, but lower intentions to look for further information, stop and stay still, go outside, and undertake safety actions. All other tests were non-significant, with *p*-values ranging from 0.114 to 0.870.

RQ3: Does Location Influence Intended EEW Actions?

There was no significant difference between regions for telling other people ($p = 0.753$), stopping, staying still, and awaiting the shaking ($p = 0.281$), taking specific protective behaviors ($p = 0.585$), or moving nearby to safety ($p = 0.522$). The overall ANOVA was significant for doing nothing, $F_{(4, 1,953)}$ – 2.41, $p < 0.05$, $\eta^2 = 0.005$, and for helping or acting to protect others, $F_{(4, 2,026)} = 2.76$, $p < 0.05$, $\eta^2 = 0.005$; however, none of the *post-hoc* comparisons approached significance. For all other comparisons, both the overall ANOVA and a number of *post-hoc* comparisons were significant; each of these actions is presented in turn below.

Looking for Further Information

Intentions to look for further information differed significantly between the geographic regions, $F_{(4, 2,003)} = 5.46$, $p < 0.01$, $\eta^2 = 0.011$. Intentions were significantly higher in Hawke's Bay/Gisborne ($M = 4.06$, $SD = 1.18$) compared to Wellington ($M = 3.53$, $SD = 1.37$, $p < 0.01$) and marginally higher compared to Canterbury ($M = 3.72$, $SD = 1.40$, $p = 0.064$). Further, the difference between Wellington and Canterbury was marginal at $p = 0.089$.

Mentally Prepare for Shaking

Intentions to mentally prepare for shaking significantly differed between the geographic regions, $F_{(4, 2,035)} = 3.32$, $p < 0.05$, $\eta^2 = 0.006$. Intentions were significantly higher in Canterbury ($M = 4.47$, $SD = 0.82$) than in Auckland ($M = 4.27$, $SD = 0.91$, $p < 0.05$), and marginally higher than in Wellington ($M = 4.35$, $SD = 0.88$, $p = 0.071$).

Go Outside

Intentions to go outside differed significantly between the geographic regions, $F_{(4, 1985)} = 14.27$, $p < 0.01$, $\eta^2 = 0.028$, with Wellington ($M = 2.41$, $SD = 1.27$) significantly lower than all other regions: Canterbury ($M = 2.80$, $SD = 1.40$, $p < 0.01$), Auckland ($M = 2.83$, $SD = 1.42$, $p < 0.01$), Hawke's Bay/Gisborne ($M = 3.00$, $SD = 1.38$, $p < 0.01$), and Otago ($M = 3.03$, $SD = 1.34$, $p < 0.01$).

Undertake Safety Actions

Intentions to undertake safety actions significantly differed between geographic regions, $F_{(4, 2,029)} = 5.35$, $p < 0.01$, $\eta^2 = 0.010$, with intentions in Wellington ($M = 3.55$, $SD = 1.29$) significantly lower than in Hawke's Bay/Gisborne ($M = 3.97$, SD

$= 1.08$, $p < 0.05$), and marginally lower than in Auckland ($M = 3.80$, $SD = 1.17$, $p = 0.075$).

Slow Down, Pull Over, and Stop Car

Intentions to slow down, pull over, and stop if driving significantly differed between geographic regions, $F_{(4, 1,965)} = 5.65$, $p < 0.01$, $\eta^2 = 0.011$, with intentions in Wellington ($M = 3.77$, $SD = 1.25$) significantly lower than in Canterbury ($M = 4.05$, $SD = 1.14$, $p < 0.01$) and marginally lower than in Otago ($M = 4.06$, $SD = 1.20$, $p = 0.069$).

DISCUSSION

This survey explored the role of previous earthquake experience in people's perceptions of the usefulness of EEW and their intended actions in response to a warning.

Perceptions of Usefulness

Our survey found that those who have had family or friends injured, or experienced damage or loss from an earthquake, saw EEW as significantly more useful, however this was a weak relationship. This is perhaps similar to the finding by Dunn et al. (2016), who found that those with earthquake experience were only slightly more likely to think EEW to be effective. However, our findings are in contrast with Santos-Reyes (2020) where perceptions of usefulness dropped after citizens received a warning too late to take effective action for a devastating earthquake, showing how experience of severe impacts can reduce perceptions of EEW usefulness. We suggest then that in absence of an operating warning system, earthquake experience perhaps does not meaningfully influence perceptions of the usefulness of EEW. Where there is a warning system, and earthquake experiences are benign, systems are generally perceived as useful, with perceptions of usefulness unaltered even when issues arise with the warning system (Nakayachi et al., 2019; Fallou et al., 2022). However, when experiences of ineffective warnings result in damage, death and injury, this is understandably where perceived usefulness declines.

As highlighted in the introduction, perceptions of EEW usefulness are important to understand, as these perceptions will affect the decisions people make in response to warnings (Lindell and Perry, 2012; Johnston et al., 2013; Becker et al., 2015; Vinnell et al., 2017). Research shows that experience influences these perceptions in different ways, but this is perhaps more evident in the context of an operating system, and is dependent on the nature of the experience (e.g., a benign vs. damaging earthquake). People's varying experiences of EEW will have implications for public education initiatives. For example, different approaches might need to be taken to enhance citizens' understanding of EEW usefulness by highlighting the benefits of taking protective actions for an EEW, tailored to what people have experienced in the past. For example, in the context of a previously damaging earthquake, this might include acknowledging previous system gaps and impacts, highlighting how a system may have been improved subsequently, and discussing the benefits of future warnings and protective actions.

Intended Responses

Despite our finding of a weak relationship between experience and perceived usefulness in a hypothetical context, we did find that previous earthquake experience influenced people's intended responses to a warning. As with much of the literature the more direct, or personally relevant, a person's experiences were of previous earthquakes, the more likely they were to intend to take useful action to a warning (Kiecolt and Nigg, 1982; Lehman and Taylor, 1987; Mileti and Darlington, 1997; Becker et al., 2017; Doyle et al., 2018).

The most relevant experience appeared to be having a family member or friend experience injury, damage or loss. People with that type of experience were more likely to anticipate undertaking protective actions to protect themselves or others. The larger number of differences in intentions between those without and those with experience involving pain or loss of close others, compared to personally feeling shaking or observing loss *via* media, suggests that differences in affect associated with types of experiences might influence behavioral intentions. The finding that people were more likely to undertake a range of potentially beneficial responses to an EEW if they had a family member or friend who had been negatively impacted by an earthquake in the past is consistent with previous work in New Zealand showing that this type of experience also relates to uptake of structural strengthening (Miranda et al., 2021). Public education initiatives could encourage people who have been harmed by earthquakes to share their experiences with their friends and family. Further, the sharing of personal experiences *via* education initiatives, linked with suggested responses to earthquake warnings, could be useful for prompting understanding and action for those without family members or friends that have had experience.

Individuals who had experienced strong shaking themselves were more likely to stop and stay still, and mentally prepare; and those who had suffered personal injury or damage were more likely to mentally prepare, pull over or help others. Those who had only observed local damage or loss, or those who had observed it *via* the media (particularly the latter) showed lower intentions to act on receipt of a warning.

We expected experience of participation in training, exercises or drills to prompt the correct intended actions for earthquake warnings (e.g., DCH, stop/stay still), but only found that those who participated in such activities were less likely to go outside, and had marginally higher intentions to mentally prepare and help or protect others. We know from previous research (Vinnell et al., 2020) that participation in drills such as ShakeOut can enhance protective actions in a real earthquake, however, it is possible that people did not associate their participation in such drills with a potential action that could be taken on receipt of a warning as they might have not yet linked these two activities in their own minds. Drills could benefit from more explanation and inclusion of EEW in future, to explain what to do when you receive an alert vs. when you feel shaking; it is largely the same but with different alerting conditions. Educational initiatives could be more explicit to link DCH with EEW situations, in addition to DCH for actual shaking (Sutton et al., 2020).

All types of experiences from direct and indirect through to vicarious experience, however, revealed that people were less likely to do nothing, highlighting the value of any kind of experience (whether direct or not) in helping people understand the importance of responding to earthquake warnings. It speaks to the question of how to enhance that experience in ways that are salient to people, so that they don't have to experience a devastating event before seeing the value of such actions.

Regional Differences

Analysis of regional differences highlighted the potential effects experience has on people's anticipated warning responses. In particular, intentions to mentally prepare on receipt of a warning were significantly higher for Canterbury region participants, most likely related to strong shaking experienced during the 2010–11 Canterbury Earthquake Sequence, which resulted in significant impacts on the region as well as loss of life (Potter et al., 2015).

Wellington region respondents were also more likely to mentally prepare on receipt of an EEW (albeit slightly less than Cantabrians), which perhaps could be related to their experience of the 2016 Mw7.8 Kaikoura earthquake, as explored in Becker et al. (2020c) and Woods et al. (2017), alongside the Mw6.2 Eketahuna earthquake (Wein et al., 2016) and Cook Strait doublet sequence in 2013 (Hudson-Doyle et al., 2018). Thus, those located in regions of Aotearoa New Zealand with the most distressing earthquake experiences valued the mental preparedness aspects of EEW greater than those in other regions who did not have that experience.

CONCLUSION

As explored by Kelman and Glantz (2014), early warning systems require not just technology but also knowledge and capacities to respond to those warnings. This is particularly important for warnings with very short timeframes such as EEW where only seconds of warning may be given before shaking, challenging the limits of sufficient time available to reduce harm or loss. Consequently, it is important to understand the environmental, social and experiential context for earthquake warnings, to identify how people might interpret and respond to such warnings, in order to guide EEW system development, including the development of drills and potentially more explicit warning messaging. This research provides insight into particular aspects of this context, namely how people's previous experiences influence perceptions of EEW usefulness and intended responses. Our findings reinforce the important role that previous experience plays in earthquake-related perceptions and behaviors, as well as inconsistencies in this role at least partially resulting from the complexities in the different possible types of experience (Bourque et al., 2012; Lindell, 2013; Becker et al., 2017; Doyle et al., 2018). Our findings suggest that, where possible, public communication and interventions could take into consideration different levels and types of experiences of the audience, for greater success. While this will work more effectively with smaller audiences, the regional differences found in this study suggest that some tailoring of public education around experiences at a regional level could further improve the effectiveness of interventions or education.

FURTHER RESEARCH

Given the limited nature of EEW in Aotearoa New Zealand, this research by necessity presents participants with hypothetical situations. Work from other countries with functional systems can inform work in the specific Aotearoa New Zealand context to an extent, but when and where it is possible, further research can test how experience influences actual EEW response, in a planned and meaningful way. This survey can act as a baseline, as EEW evolves in Aotearoa New Zealand and the population receives warnings. Re-administering relevant parts of the survey would enable reporting and analysis of how people's knowledge, perceptions, attitudes, intentions and actions evolve over time with EEW system development. This could be supplemented by qualitative research to fully understand the nuances and influences of such factors as a system develops.

Future research could also include more studies on EEW performance, including testing of the proposed algorithms combined with testing of the proposed alerting channels, to determine how much time people in Aotearoa New Zealand may have to respond to an alert. Additionally, in New Zealand, emergency mobile alerts (which are more similar to EEWs than other warnings such as flood sirens) have been sent for hazards such as expected or potential tsunami impacts (Vinnell et al., 2022). While the public tend to appreciate these warnings, there are misconceptions about how and when they are used (e.g., some people want an alert to tell them they are *not* at risk) which makes comparisons to EEW difficult. Future research could explore how people's experiences with other warning systems influence their expectations and engagement with EEW.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article via references to other papers, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements (see Massey University Low Risk Notification no: 4000019302). Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

JB, SP, KN, and SM developed the survey. JB and SP undertook data collection. JB, LV, and KN analyzed the survey data. All authors contributed to writing the manuscript.

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