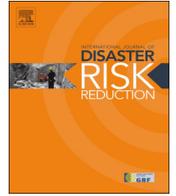




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# Are two earthquakes better than one? How earthquakes in two different regions affect risk judgments and preparation in three locations <sup>☆</sup>



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## ABSTRACT

Research has shown that experiencing a single disaster influences people's risk judgments about the hazard, but few studies have studied how multiple disasters in different locations affect risk judgments. Following two earthquake sequences in two different regions (Christchurch, Cook Strait), this study examined earthquake risk judgments, non-fatalism and preparation in two New Zealand cities that were near to one of those sequences (Christchurch in Canterbury, Wellington near Cook Strait) and in one city that was distant from both events (Palmerston North). Judgments of earthquake likelihood were higher after the Cook Strait earthquakes than before in Christchurch and the rest of New Zealand, but not in Wellington, where the baseline risk was high. However, participants in all cities saw the risk as more real, plausible, and important after these earthquakes, particularly in Wellington. Preparations following the earthquakes were also higher in Wellington and Christchurch (where non-fatalism was highest) than in Palmerston North. Causal attributions for (not) preparing differed across the three cities, as did non-fatalism. These findings suggest that the Christchurch and Cook Strait earthquakes had a combined effect on citizens' perception of the risk, particularly in Wellington. Such events create a valuable window of opportunity for agencies wishing to enhance preparedness.

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## 1. Introduction

In September 2010 and February 2011, earthquakes struck near Christchurch city in Canterbury, New Zealand, resulting in 185 fatalities and \$40 billion in damage, over 20% of GDP (New Zealand Treasury 2013). Most New Zealand citizens had expected an earthquake near Wellington, which sits near several major faults, rather than Christchurch. Two years later in 2013, a series of earthquakes occurred in the Cook Strait (and Seddon near the Strait), near the city of Wellington. These earthquakes incurred no deaths but seriously damaged a number of buildings and gave

Wellington citizens a taste of major shaking that many had not experienced before. What effect did these two series of events following in quick succession have on New Zealanders' judgments of earthquake risk and their preparation?

### 1.1. Risk judgments about natural disasters

Citizens' risk judgments are not sufficient to get them to prepare, but recognition of the risk is a prerequisite to preparation [21]. Few people prepare if they think there is no likelihood of an earthquake. People often discount low frequency events like earthquakes and fail to prepare for them while prioritising risks from more frequent events that may have minor consequences [38]. In addition, people often hold unrealistic optimism and see themselves as less at risk from hazards than others [35]. This bias occurs with natural hazards such as hurricanes and tornados [33,45], and earthquakes [4,12,26,40]. This optimistic bias is highest for rare events such as earthquakes [8] and is resistant to change [47].

Risk judgments and optimism are influenced by experiencing a hazard, although such effects depend on other factors. Where

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people suffer damage from hazards, they elevate the risk from that hazard and are less optimistic [18,21,48]. Experience of a hazard makes the risk more available in citizens' thinking [46], and people directly exposed to hazards see the risk as higher than people who are distant from the events [50]. However, when people suffer no ill effects from a hazard event, the opposite effect occurs where they show a 'normalisation bias' and discount the risk of that hazard [15,26,27].

Judgments of the risk from hazards also reflect baseline probabilities and expectancies; if people expect a hazard before it occurs, their judgment of the likelihood of that hazard may not increase when they experience it [1,16,23]. McClure et al. [24] showed that when an earthquake happens in an unexpected place (as in Christchurch in 2011), the event has different effects on risk judgments in different locations. In their recall of the earthquake likelihood *before* the Christchurch earthquakes,<sup>1</sup> participants judged an earthquake more likely in Wellington, where an earthquake was expected but did not occur, than in Christchurch, where an earthquake was not expected but did occur. These judgments show the effects of expectancies, as Wellington has a history of damaging earthquakes (notably in 1848, 1855 and 1942) and scientists have long predicted more earthquakes there [19]. In contrast, *after* the Christchurch earthquakes, participants saw a future earthquake as equally likely in Christchurch and Wellington, showing that the experience of a disaster in an unexpected location (Christchurch) sharpens judgments of risk. Thus participants' base rate expectancy of an earthquake was previously higher for Wellington [5,6], but increased in Christchurch after the Christchurch earthquakes.

### 1.2. The effect of multiple events on risk judgments and preparation

Much research on risk judgments following natural disasters has examined the effects of experiencing a single disaster on judgments of the risk from that hazard [4,11,12,20,36,45]. Some studies have shown the effects of multiple tornadoes, but these were all in the same region (see [50]). Research in other domains suggests that multiple events augment risk judgments more than a single event [37]. However, few studies have studied the effects of multiple hazards in different locations on citizens' judgments of the risk from those hazards.

One exception that has studied the effect of multiple hazard events is Russell et al. [32], who examined preparedness before and after the 1987 Whittier Narrows earthquake near Los Angeles and the 1989 Loma Prieta earthquake near San Francisco. Russell et al. [32] found that preparation increased over this period. In addition, mitigation actions increased after the earthquakes, especially in San Francisco, which experienced the damaging Loma Prieta earthquake. The study did not examine changes in citizens' perception of the likelihood of earthquakes, although it did show that having frequent thoughts about earthquakes predicted more preparation. A second study focusing on multiple events in different locations examined citizens' risk judgments about tornadoes, which are more common than damaging earthquakes [48]. The study compared risk judgments and optimism in three towns recently struck by tornadoes with two control towns in states with similar tornado frequencies that were not struck by these tornadoes. Optimistic risk judgments were lower in impact towns than in control towns, yet they did not completely subside.

A similar sequence of events to those studied by Russell et al. [32] recently occurred in New Zealand. The 2010–2011

Christchurch earthquakes caused 185 deaths and \$40 billion in damage. Two years later, a second series of earthquakes occurred in July and August 2013 in Cook Strait and Seddon, both close to Wellington (50 km and 80 km respectively). Wellington is the third largest city in New Zealand (population 300,000) and a major earthquake has long been expected there, due to its proximity to multiple faults.

Although no deaths resulted from the 2013 Cook Strait earthquakes, these events were widely felt as strong shaking in Wellington and a number of buildings were damaged [14]. Maximum peak ground acceleration (PGA) in Wellington City was 0.2 g for the July earthquake (Cook Strait) and 0.26 g for the August one (Seddon), making these earthquakes the most severe in Wellington since 1977 [10,14]. There were also a significant number of EQC (Earthquake Commission) insurance claims; these were concentrated in Wellington more than cities further from the earthquakes. For example, for the 21 July 2013 earthquake, there were 1863 EQC claims in Wellington, 80 in Palmerston North and 37 in Christchurch (Bede Dwyer, EQC). There were similar proportions of claims for the August event.

### 1.3. The present study

Most Wellington citizens were very aware of the earlier Christchurch earthquakes and had friends or relatives in that region [24], but they did not directly experience these events. In contrast, they did feel strong shaking from the Cook Strait events. The question we examined here is what effect these two sets of events (Christchurch and Cook Strait earthquakes) had on citizens' judgments of the likelihood of earthquakes and preparation in three cities: Wellington, whose citizens did not directly experience the Christchurch earthquakes but who did feel strong shaking from the Cook Strait earthquakes; Christchurch, where the major earthquakes occurred in 2010–2011 but was further from the Cook Strait earthquakes (approx. 300 km); and Palmerston North, which did not directly feel either series of earthquakes and where citizens had a lower expectancy of a future earthquake [31]. Palmerston North thus served as a comparison group for the two more directly affected locations (Wellington and Christchurch), similar to Weinstein et al.'s [48] study.

Thus a key issue we examined here is: How did people respond after the two major earthquake sequences in Christchurch and Cook Strait, which is closer to Wellington? We expected that these two events would affect people in Wellington more than Christchurch, because Christchurch citizens had directly experienced major earthquakes just two years earlier, and could be expected to judge earthquakes equally likely before and after the Cook Strait earthquakes and to prepare more before the Cook Strait earthquakes. In contrast, Wellington citizens were directly exposed to the strong shaking from the Cook Strait earthquakes only two years after they had seen the major effects of the earthquakes in Christchurch. So Wellington citizens had the combined experience of the vicarious knowledge of the Christchurch earthquakes and the direct experience of the Cook Strait earthquakes. We anticipated that these two events would act as a sharp wake up call to Wellington citizens who did not recognise the risk or prepare after the Christchurch events.

For risk measures, we assessed judgments of earthquake likelihood for different regions and added two new measures assessing judgments that the risk is more real, plausible and important since the Cook Strait earthquakes. We thought that these new measures would be less vulnerable than the likelihood measures to hindsight bias, where recall judgments are coloured by subsequent events [9]. New Zealand citizens expected an earthquake in Wellington prior to these two earthquake sequences [1,24], so we expected any 'wake-up' effect after the Cook Strait events to

<sup>1</sup> Of the two earthquakes in the province of Canterbury in 2010 and 2011, only the 2011 earthquake was directly in Christchurch, but we refer in this paper to 'the Christchurch earthquakes' to prevent confusion from using multiple place names.

appear in judgments that the risk from earthquakes is more real, plausible and important, rather than increased ratings of earthquake likelihood.

We made the following predictions: first, with regard to earthquake likelihood judgments, we predicted that participants in all three locations (Wellington, Christchurch, Palmerston North) would judge earthquakes more likely after these earthquakes than they recalled before the earthquakes. Second, with regard to differences across participant cities, we predicted that Wellington participants would see the risk of earthquakes as more real, plausible and important after the Cook Strait earthquakes, would prepare more than other participants, and would attribute their preparations more to the Christchurch earthquakes being a wake-up call than other participants. Third, we predicted that Christchurch participants would be less fatalistic about the value of preparation, due to their exposure to the beneficial effects of preparation in the Christchurch earthquakes in 2010–2011, and that Wellington and Palmerston North participants would have similar levels of non-fatalism.

## 2. Method

### 2.1. Participants

Participants were in three locations in New Zealand: Wellington ( $N=106$ ), Christchurch ( $N=156$ ), and Palmerston North ( $N=120$ ). The Cook Strait earthquakes were close to Wellington, where a major earthquake has been expected, and were 240 straight kilometres from Christchurch, which experienced major earthquakes in 2010 and 2011, and 195 km from Palmerston North, which has experienced no major earthquakes in recent times.

Data in the three cities were collected in November 2013, four months following the Cook Strait earthquakes, after receiving ethics approval for the Human Ethics Committee of Victoria University of Wellington. Participants were recruited from popular market squares and parks in the three cities. The Wellington sample of 106 participants comprised 32 men and 47 women (27=unstated) with a mean of 0.82 children per household. The Christchurch sample comprised 156 participants (gender: male=44, female=67, unstated=45) with a mean of 0.92 children. The Palmerston North sample of 120 participants (gender: male=36, female=45, unstated=39) had a mean of 1.44 children per household.

### 2.2. Materials/procedure

To address the predictions, questions compared judgments of earthquake likelihood for the same three locations: the two most directly affected cities (Wellington and Christchurch) and the rest of New Zealand. This design differs from that in McClure et al. [24], where participants in Christchurch, Wellington, and Palmerston North rated earthquake likelihoods in their own city, in Christchurch, and in the rest of NZ. Thus in the present study, citizens in Palmerston North did not rate earthquake likelihood in their own city. Our rationale was to get judgments of earthquake likelihood about the same locations from all participants and use citizens in Palmerston North as a comparison group who experienced neither series of earthquakes.

Questions first assessed the perceived earthquake likelihood of a big earthquake occurring *before* (recall data) and *after* the Cook Strait earthquakes in three locations: Wellington, Christchurch, and another part of New Zealand. Participants responded on a 5-point Likert scale with anchor points labelled 1='Not at all likely' and 5='Very likely'. We created two new questions asking whether the risk of an earthquake was more real or plausible since

**Table 1**

Types of preparation and attributions before and after the Cook Strait earthquakes for (not) preparing (participants tick those that apply). Each category also had an 'other' option.

Types of preparation
1. Got basic needs e.g. canned food, water, emergency kit, torch, batteries, battery radio
2. Contents damage mitigation e.g. attach shelves to wall, shift heavy objects to lower levels
3. Structural damage mitigation; e.g. quake-safe the house, or check it's safe, remove brick chimney
4. Logistics/planning e.g., planned where to meet
<b>Attributions for preparing</b>
1. My personality, e.g., I'm a sensible person
2. Just in case of an emergency
3. I thought an earthquake might happen
4. The Canterbury earthquake and damage was a wake-up call for me
5. Advice from media, education
<b>Attributions for not preparing</b>
1. My personality e.g., I'm complacent, lazy, or unorganised and did not get around to it
2. I did not think about it
3. I thought an earthquake would not happen - that it was not a serious risk
4. I thought there would not be another big earthquake so soon after the Canterbury [Christchurch] earthquakes
5. I did not take advice from the media seriously

the Cook Strait earthquakes, and whether the combined occurrence of the Christchurch and the Cook Strait earthquakes increased participants' feeling that earthquakes were an important risk for them and their region. These questions enabled participants from Palmerston North to rate the salience of earthquake risk, despite not rating the likelihood of an earthquake in their own city.

We also examined participants' preparation, attributions for their (lack of) preparation and non-fatalism. Questions about preparation [24] asked firstly whether participants had made any earthquake preparations before and after the Cook Strait earthquakes, and secondly which of five types of preparation they had made (see Table 1). Questions also asked participants to select the main reason for preparing or not preparing from a list of attributions (Table 1), adapted from McClure et al. [24].

One question assessed non-fatalistic beliefs by asking if preparation for earthquakes is likely to reduce harm and loss from a very big earthquake. Questions also asked whether participants incurred any damage during the Cook Strait earthquakes, if they knew anyone close to them who lives in Seddon (near Cook Strait), and if they knew anyone who incurred damage during either the Cook Strait or the Christchurch earthquakes. Demographics included gender, age, number of dependent children per household and suburb. Participants were told the questionnaire was about earthquakes but not the specific hypotheses.

## 3. Results

A correlation matrix is shown in Table 2. This shows that participants' feeling that earthquakes are an important risk in their region correlated with their judgment of the likelihood of earthquakes since the Cook Strait earthquakes. Interestingly, judgments that the risk was more real and plausible correlated negatively with judgments of the likelihood of earthquakes in Wellington (recall) and the rest of NZ (recall and after).

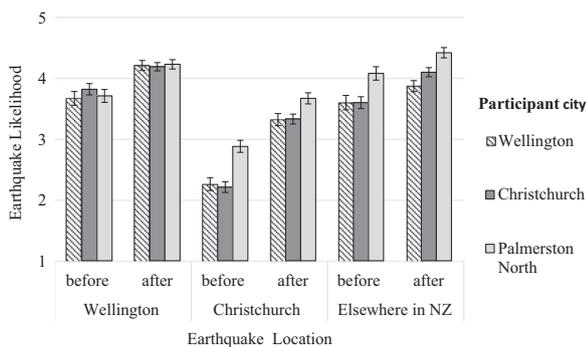
### 3.1. Expectancies of a large earthquake before and after the cook strait earthquakes

Fig. 1 shows the mean ratings of the likelihood of an

**Table 2**  
Correlation matrix.

	1	2	3	4	5	6	7	8	9	10	11	12
1. Wellington recall	1											
2. Wellington after	.51**	1										
3. Christchurch recall	.18*	.13*	1									
4. Christchurch after	.12*	.30**	.26**	1								
5. NZ recall	.44**	.28**	.32**	.10*	1							
6. NZ after	.31**	.38**	.11*	.22**	.53**	1						
7. Risk more real	-.13*	.07	-.09	.09	-.18**	-.13*	1					
8. Combined EQs	.21**	.33**	.10	.30**	.11*	.21**	.11*	1				
9. Preparation before EQ	.16**	.11*	.07	.08	.08	.05	-.08	.24**	1			
10. Preparations since EQ	-.02	.02	-.05	.13	-.08	-.03	.18*	.20**	.17**	1		
11. Non-fatalism	.21**	.20**	-.03	.04	.11*	.12*	.04	.16**	.14**	-.09	1	
12. Did you incur damage	.07	.04	-.05	.05	-.03	-.02	.08	.09	.18**	.09	.07	1

\*  $p < .05$  (two tailed).  
\*\*  $p < .01$  (two tailed).



**Fig. 1.** Mean ratings of the likelihood of an earthquake in the three locations.

earthquake in the three locations before and after the Cook Strait earthquakes. To test our predictions about these judgments, we performed a 3 (Participant city: Christchurch, Wellington, Palmerston North) × 3 (Earthquake location: Christchurch, Wellington, other part of NZ) × 2 (Time: Before, After) mixed design ANOVA on likelihood ratings. The multivariate tests showed that first, as predicted, participants judged an earthquake more likely after the Cook Strait earthquakes ( $M=3.89$ ,  $SE=0.04$ ) than they recalled before the earthquakes ( $M=3.31$ ,  $SE=0.04$ ),  $F(1, 375)=205.69$ ,  $p < .001$ ,  $\eta^2=.35$ . Second, participants thought a large earthquake was more likely in Wellington ( $M=3.97$ ,  $SE=0.04$ ) and in another part of New Zealand (hereafter called 'elsewhere') ( $M=3.93$ ,  $SE=0.05$ ) than Christchurch ( $M=2.99$ ,  $SE=0.04$ ),  $F(2, 378)=230.73$ ,  $p < .001$ ,  $\eta^2=.55$ . Third, Palmerston North participants judged an earthquake more likely than those in Christchurch and Wellington,  $F(2, 375)=7.51$ ,  $p < .001$ ,  $\eta^2=.04$ .

These main effects are qualified by two interactions. There was a 2-way interaction between earthquake location and time,  $F(2, 756)=28.12$ ,  $p < .001$ ,  $\eta^2=.07$ . As shown in Fig. 1, prior to the Cook Strait earthquakes, participants recalled judging the likelihood of earthquakes in Wellington or elsewhere higher than in Christchurch. After the earthquakes, this likelihood increased more in Christchurch ( $M=0.91$ ) than in Wellington ( $M=0.48$ ) or elsewhere ( $M=0.41$ ),  $F(2, 754)=30.32$ ,  $p < .001$ ,  $\eta^2=.07$ , although it was still lower in Christchurch than the other two locations.

There was a 3-way interaction between participant city, earthquake location, and time,  $F(4, 756)=6.63$ ,  $p < .001$ ,  $\eta^2=.03$ . As shown in Fig. 1, participants in the three cities judged an earthquake in Wellington equally likely prior to the earthquakes,  $F(2, 377)=0.46$ ,  $ns$ , and after the earthquakes,  $F(2, 378)=0.11$ ,  $ns$ . In contrast, Palmerston North participants judged an earthquake more likely in Christchurch,  $F(2, 378)=14.92$ ,  $p < .001$ , and elsewhere in NZ,  $F(2, 377)=8.72$ ,  $p < .001$ , after the earthquakes than

other participants.

### 3.2. Was the earthquake risk more real and important after the Cook Strait earthquakes?

On the question asking if participants thought the risk of a future big earthquake was more real and plausible since the Cook Strait earthquakes, 89% of participants said yes, with no difference for participant city,  $\chi^2(2)=2.14$ ,  $ns$ . There were however differences across cities on whether the combined occurrence of the Christchurch and Cook Strait earthquakes increased participants' feeling that earthquakes are an important risk in their region,  $F(2, 376)=6.00$ ,  $p < .01$ ,  $\eta^2=.03$ . Post hoc Bonferroni tests ( $p < .05$ ) showed that the earthquake risk was judged more important by participants in Wellington ( $M=4.25$ ,  $SD=0.94$ ) than in Christchurch ( $M=3.94$ ,  $SD=1.00$ ) and Palmerston North ( $M=3.79$ ,  $SD=1.06$ ).

### 3.3. Having acquaintances near the earthquake, incurring damage and non-fatalism

A mixed design ANOVA showed no difference in participants from Wellington and Christchurch who did (20%) or did not (80%) have close acquaintances near Cook Strait on the likelihood of an earthquake in their own city,  $F(1, 252)=0.44$ ,  $ns$ . An ANOVA on whether people had incurred damage showed that participants from Christchurch ( $M=2.37$ ,  $SD=1.33$ ) reported more damage in the earthquakes than those from Wellington ( $M=1.36$ ,  $SD=0.82$ ) or Palmerston North ( $M=1.17$ ,  $SD=0.61$ ),  $F(2, 370)=55.38$ ,  $p < .001$ ,  $\eta^2=.23$ . It is likely that this result reflects the huge damage in the Christchurch earthquakes. Because of the low numbers at the extremes of the scale, data were grouped into two cells: no or low damage (ratings 1 or 2,  $N=291$ ) and moderate to high damage (ratings 3–5,  $N=80$ ). A mixed design ANOVA showed that having suffered damage had no relation to judgments of earthquake likelihood,  $F(8, 740)=0.52$ ,  $ns$ .

An ANOVA on the non-fatalism question showed that participant city related to judgments of non-fatalism (i.e., the belief that strengthening earthquake-prone buildings is likely to reduce the risk of harm and loss),  $F(2, 366)=2.92$ ,  $p < .05$ . Participants in Christchurch ( $M=4.12$ ,  $SD=1.15$ ) were less fatalistic than participants in Palmerston North (Palmerston North,  $M=3.81$ ,  $SD=1.06$ ),  $F(1, 269)=5.83$ ,  $p < .001$ . Wellington non-fatalism scores fell in between ( $M=4.12$ ,  $SD=1.15$ ). Low fatalism correlated with preparation before the earthquakes.

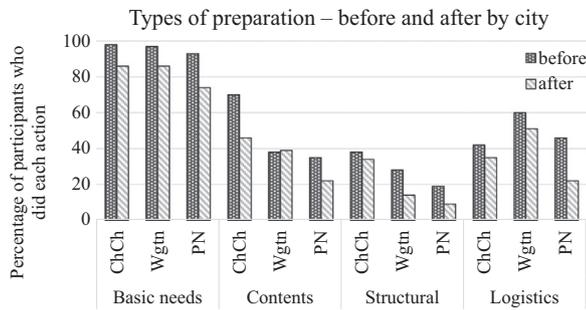


Fig. 2. Types of preparation – before and after (percentage of those who did each action). ChCh=Christchurch, Wgtn=Wellington, PN=Palmerston North. Data for ‘Other’ were a low proportion of the sample and are not reported.

3.4. Preparation

The proportion of participants who reported preparing for an earthquake before and after the Cook Strait earthquakes differed by city. More participants recalled preparing *before* the earthquakes in Christchurch (65%) and Wellington (60%) than in Palmerston North (45%),  $\chi^2(2)=11.65, p < .01$ , Cramer’s  $V=.18$ . In contrast, *after* the earthquakes, more people prepared in Wellington (74%) than in Christchurch (58%) and Palmerston North (46%),  $\chi^2(2)=19.63, p < .001$ , Cramer’s  $V=.23$ .

Preparation *before* the earthquakes correlates with the likelihood of an earthquake in Wellington,  $r(367)=.16, p < .01$ , but not in Christchurch or elsewhere (Table 2). In contrast, *after* the earthquakes, preparation relates to seeing the risk as more real and plausible,  $r(378)=.18, p < .001$ , and their increased feeling that earthquakes are an important risk in their region  $r(378)=.20, p < .001$ .

Fig. 2 shows the types of preparations people reported. Chi square analyses show that across all cities, more participants prepared before than after the earthquakes,  $p < .05$ . The cities differed three actions. On actions to mitigate damage to contents, *before* the earthquakes more participants acted in Christchurch than the other two cities,  $\chi^2(2)=23.67, p < .001$ , whereas *after* the earthquakes more participants acted in Christchurch and Wellington than Palmerston North:  $\chi^2(2)=8.57, p < .05$ . On actions to mitigate structural damage, more participants acted in Christchurch than the other cities, both *before*,  $\chi^2(2)=6.63, p < .05$ , and *after* the earthquakes,  $\chi^2(2)=16.62, p < .001$ . Logistics did not differ across locations *before* the earthquakes,  $\chi^2(2)=5.27, p > .05$ , but *after* the earthquakes, more acted in Wellington than in Christchurch and Palmerston North,  $\chi^2(2)=11.34, p < .05$ .

3.5. Attributions for (not) preparing

Fig. 3 shows the reasons participants cited for preparing. All reasons had higher frequencies before the earthquakes than after

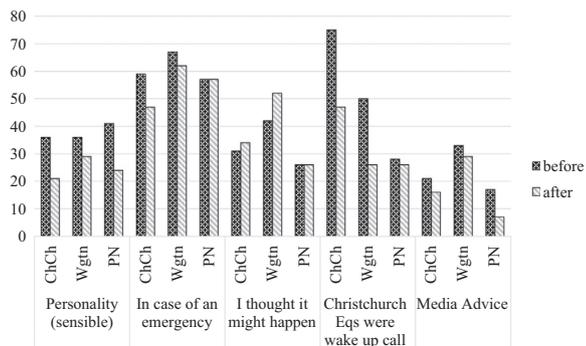


Fig. 3. Reasons for preparation – percent of those who said they did prepare.

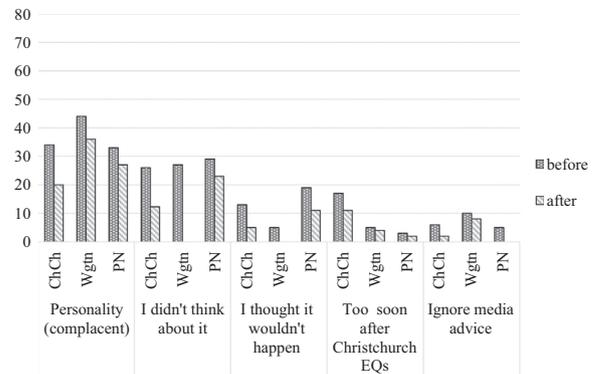


Fig. 4. Reasons for not preparing. Percent of those who said they did not prepare.

(all  $p < .05$ ). Participants in Palmerston North were lower than the other two cities on the wake-up call item,  $\chi^2(2)=33.16, p > .001$ , Cramer’s  $V=.39$ , and on ‘I thought it might happen’, ‘Media advice’ and ‘wake-up call’ *after* the earthquakes,  $\chi^2(2)=10.24, p > .05$ , Cramer’s  $V=.22$ ;  $\chi^2(2)=10.17, p > .05$ , Cramer’s  $V=.22$ ,  $\chi^2(2)=10.46, p > .05$ , Cramer’s  $V=.22$ .

Fig. 4 shows the reasons for *not* preparing, which were higher before the earthquakes than after,  $p < .05$ , except for ‘Ignore media advice’. Before the earthquakes, Christchurch participants were higher on ‘Too soon after’,  $\chi^2(2)=8.32, p > .05$ , Cramer’s  $V=.23$ , whereas after the earthquakes, Wellington participants were higher on ‘Ignore media advice’,  $\chi^2(2)=6.12, p > .05$ , Cramer’s  $V=.20$  and lower on ‘I did not think about it’,  $\chi^2(2)=8.38, p > .05$ , Cramer’s  $V=.23$ . In the ‘other’ option, several said they had adequate preparations in place.

4. Discussion

4.1. Judgments of earthquake likelihood before and after the Cook Strait earthquakes

As predicted, participants judged an earthquake more likely for all three locations after the Cook Strait earthquakes than they recalled before. This finding supports previous findings that people judge hazards more likely after experiencing those hazards [11,22], especially in comparison to control groups in other locations [32,48]. This likelihood judgment correlates with participants’ judgments that the combined occurrence of the Christchurch and Cook Strait earthquakes increased their feeling that earthquakes are an important risk, which suggests that the risk is to some extent personalised. However, likelihood judgments (especially before the earthquakes) correlate *negatively* with judgments that the risk is more real and plausible. This interesting finding is likely to reflect a real difference rather than a bias, as people who see earthquakes as unlikely before an earthquake occurs are more likely to see the risk as real and plausible when earthquakes do occur.

More surprising is participants’ view of where earthquakes are likely, particularly their judgment that earthquakes were less likely in Christchurch than Wellington before the Cook Strait earthquakes. These earthquakes occurred only two years after the damaging Christchurch earthquakes, and we expected the risk estimates for Christchurch to be higher, consistent with findings soon after the Christchurch earthquakes, two years prior to this study [24]. This result shows how the effects of a damaging earthquake on judgments of earthquake likelihood can dissipate over time (cf. [4]).

There are several possible interpretations of this result. First, although the measure of earthquake likelihood asked for

judgments 'before the July/August Cook Strait/Seddon earthquakes', some participants may have reported the likelihood before the Christchurch earthquakes. It is pertinent that the likelihood judgments after the earthquakes increased more in Christchurch than the other two locations. An alternative interpretation of this result is that when the aftershocks in Christchurch reduced in 2012–2013, participants made a 'gamblers fallacy' judgment that Christchurch had received 'its share' of earthquakes [48]. This result suggests that New Zealand citizens are reverting to their earlier view that an earthquake is less likely in Christchurch than in Wellington, where earthquakes are expected [1]. It is as if they saw the Christchurch earthquakes as a short term anomaly. Another possibility is that when rating the likelihood of an earthquake in Christchurch, participants judged the likelihood of a future aftershock specific to the 2010–2011 Christchurch earthquake sequence. As there have been few major aftershocks in this sequence since December 2011, participants may have judged that the sequence was finished or 'de-pressurised', lowering their perceived base rate for this event and the region [5].

#### 4.2. The relation of participant location to likelihood judgments

A second interesting finding is the effect for participant city, where in their recall of before the Cook Strait earthquakes, participants from Palmerston North judged an earthquake more likely in Christchurch and in the rest of New Zealand than the participants in the other two cities. Why this difference? One possibility is that Wellington and Christchurch participants live in cities for which earthquake likelihood judgments were made in this study. Also Christchurch and Wellington citizens had experienced recent earthquakes and now had direct and vicarious experience of recent earthquakes, whereas those in Palmerston North had not. The experience of a natural disaster is more dramatic and emotional than people expect [36]. This experience may have led participants in Christchurch and Wellington to feel that previously they did not expect anything like what they actually experienced; so they rated the pre-event likelihood lower than did persons in Palmerston North. This 'hindsight bias' interpretation [9] is supported by participants' judgment that the combined occurrence of the two earthquake sequences increased their feeling that earthquakes were an important risk for them and their region; this was higher in Wellington and Christchurch than Palmerston North. Palmerston North could be seen as the outlier, but their response may be the norm for cities not affected by an earthquake.

In contrast with the likelihood judgments for Christchurch and the rest of NZ, participants from all three cities judged the likelihood of an earthquake in Wellington similarly. Citizens across New Zealand had long expected an earthquake in Wellington, based on GNS (Science) forecasts, the news media [1] and its history of earthquakes.

#### 4.3. Preparation, non-fatalism and attributions

Preparation after the Cook Strait earthquakes showed a positive relationship to seeing the risk as more real and plausible and the feeling that earthquakes are an important risk in their region. This relationship suggests that these novel measures of perceived risk are more valuable in predicting preparation than measures of whether an earthquake is likely, which showed a weak relationship with preparation. Other research has shown that measures of likelihood judgments that use verbal descriptions of probabilities lack reliability and validity. There is wide variability in the interpretation of words used to describe probabilities, such as 'likely' or 'extremely high chance' [3,17]. Such verbal expressions lack a common definition and are interpreted as a wide range of probabilities.

In addition to expected patterns of preparation, such as participants reporting more 'basic needs' actions than structural mitigation [41], the data have several interesting features. The finding that participants reported preparing more before the Cook Strait earthquakes than after is likely to be because the study was run only five months after these earthquakes and allowed less time for preparation. This especially applies to damage mitigation actions, which may take a long time. In addition, some participants had made preparations after the Christchurch earthquakes, particularly in Christchurch [24], so these actions did not need repeating after the Cook Strait earthquakes. You can only remove a brick chimney once.

Notwithstanding this overall pattern of lower preparation after the earthquakes, preparation differed across the three cities. Most notably, whereas actions to mitigate damage were less frequent after the Cook Strait earthquakes in Christchurch and Palmerston North, there was no such decrease in Wellington. This difference suggests that the two earthquake sequences served as a wakeup call in nearby Wellington more than the other two cities, particularly Palmerston North, which experienced neither earthquake sequence [46].

This interpretation is supported by the attribution data, where participants who did prepare said they did so in case of an emergency, because they thought it might happen and because the Christchurch earthquakes were a wake-up call. These attributions were cited more in Wellington and Christchurch than Palmerston North, consistent with the earthquake likelihood judgments and preparation. On attributions for *not* preparing after the Cook Strait earthquakes, not a single person in Wellington said they didn't think about it, suggesting availability of the hazard was high [48]. The lower preparation in Palmerston North is consistent with findings that people who are distant from an event discount the risk [50].

This interpretation of the risk perceptions and higher preparation in Wellington is reinforced by reports of an acceleration in the upgrading and demolition of earthquake-prone public buildings in Wellington since the Cook Strait earthquakes, with five buildings a month coming off the list of 700 such buildings [34]. If this upgrading rate is maintained, all 700 would be dealt with in just 12 years. In addition, since these earthquakes, Wellington has seen a trend of tenants shifting from earthquake-prone buildings to more resilient buildings [44]. These patterns are consistent with the finding that after these two earthquake sequences, Wellington citizens see the earthquake risk as more real and important.

Non-Fatalism about the value of action to mitigate damage to buildings was higher in Christchurch than in Palmerston North (Wellington fell in between). This higher efficacy in Christchurch may reflect the direct experience of the 2010–2011 earthquakes with the clear evidence of better outcomes for buildings that met building standards. It is noteworthy in this regard that the only preparation where Christchurch was higher than the other two cities was on actions to mitigate damage.

This research focuses on citizens' judgment of earthquake risk and preparation across different locations. We note that judgments that a hazard is likely are not sufficient for people to prepare (e.g., [7,22,29,39]). People need to also understand how preparations influence outcomes [2] and believe that preparation is effective and worth the cost [22,30,42]. However, recognition of the risk is a prerequisite for voluntary action, so risk communications should frame risks in effective ways [13,25,43].

#### 4.4. Limitations

We have suggested that citizens' perception of earthquake likelihood and risk (especially in Wellington) is an outcome of the

two series of earthquakes in Christchurch and Cook Strait. There is no way to absolutely prove this interpretation and it is possible that the risk perceptions and preparation in Wellington simply reflect the recent Cook Strait earthquakes or other factors. However, Wellington participants did indicate that the combined effects of the two earthquake sequences led them to see the risk as important. In addition, based on prior levels of risk perception and preparation [1,24], it is unlikely that the level of post-Cook Strait preparation in Wellington seen in this study and elsewhere [34] would have occurred without the combined effect of the two earthquake sequences. It is possible that some Christchurch citizens may have declined to participate due to distrust about the Canterbury earthquakes.

#### 4.5. Conclusions

These findings clarify how the experience of two earthquake sequences in different locations relates to people's perception of earthquake likelihood, their preparation and their attributions for (not) preparing. These broad effects relate to citizens' location and proximity to the events. Silver and Wortman [37] showed that the experience of two negative events can increase helplessness and impede recovery after these events [23]. In contrast, as with Russell et al. [32] and Weinstein et al. [48], our results suggest that two hazard events in different locations can have positive effects in getting home the message that people in vulnerable regions need to prepare. The pattern of risk judgments, preparation and attributions all support this conclusion.

If the Cook Strait earthquakes had occurred in isolation and not been preceded by the damaging Christchurch earthquake sequence, we speculate that citizens in Wellington would have quickly forgotten about the Cook Strait events in 3–6 months, maybe earlier. But the Cook Strait earthquakes rode on the tail of the Christchurch earthquakes, which led to major destruction in one of New Zealand's largest cities. The data suggest that the two earthquake sequences are having a lasting impact, particularly in Wellington, where people see the risk is more real and extensive retrofitting of buildings is ongoing. These findings should also apply to more frequent disasters such as floods and tornadoes, where the occurrence of two events in different locations is relatively common [48].

Agencies cannot simulate earthquakes to get citizens to take the risk seriously. But they can exploit the window of opportunity created by two earthquake series occurring in close temporal proximity [43,49], even if these events are in distant locations. Also, where no local earthquakes occur, agencies can enhance risk judgments by prompting vicarious experience of hazard events [21] and identification with disasters in other countries [38]. An example is when the Fukushima cascading disaster in Japan affected risk judgments about nuclear power plants as far away as Germany [28]. A key issue is understanding what factors lead people to see a distant event as relevant to their own risk from the same hazard, as occurred with Fukushima and the Christchurch earthquakes.

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