

# Homeowners' Perceptions of Seismic Building Performance and Implications for Preparedness in New Zealand

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**Abstract:** Over the last decade, engineering studies have mentioned the need for meeting societal demands of damage expectations and housing performance for major earthquakes. However, they do not refer to any systematic analysis examining such societal demands, nor have they investigated interactions of this with voluntary seismic strengthening. A questionnaire distributed to homeowners of wooden-framed houses in the Wellington region of New Zealand investigated these issues. Survey respondents expected a better seismic performance of their house after voluntarily undertaking structural strengthening (i.e., positive outcome expectancy) and expected a better seismic performance of their house, regardless of the use of strengthening, than what is accepted by current seismic codes, which aim for life safety (i.e., collapse prevention). Although this study found that experience of damage in past earthquakes was not associated with final implementation of such preparedness measures, access to strengthening information and trust toward providers of information, such as builders, were found to play a key role when adopting strengthening. This study gives insight into the role that outcome expectancy and sources of information play in voluntary structural strengthening of residential low-rise buildings and indicates a need for better engagement, such as working closer with builders as sources of information, to reduce losses in future major earthquakes. DOI: [10.1061/\(ASCE\)NH.1527-6996.0000600](https://doi.org/10.1061/(ASCE)NH.1527-6996.0000600). This work is made available under the terms of the Creative Commons Attribution 4.0 International license, <https://creativecommons.org/licenses/by/4.0/>.

**Author keywords:** Earthquake preparedness; Outcome expectancy; Building strengthening; Earthquake experience; Mitigation.

## Introduction

New Zealand (for which the current Māori-language name is Aotearoa) is one of many countries vulnerable to multiple natural hazards including earthquakes, tsunami, volcanic eruption, and high-impact weather events. Many of the natural hazards faced by the Wellington Region—New Zealand's capital—have been earthquakes. The five active faults—Wairarapa, Wellington, Ohariu, Shepherds Gully/Pukerua, and Wairau—combined with the high population in the area make it one of the highest-risk earthquake areas in New Zealand (Van Dissen and Berryman 1996). The last significant earthquake was the 1855 Wairarapa earthquake, and studies in the area indicated that a Wellington fault earthquake event is delayed by 250 years (Robinson et al. 2011). The risk

is heightened by the fact that the Wellington Fault passes directly through urbanized areas. In addition, Wellington is located at the southwestern tip of the North Island, resulting in added risk from the Hikurangi subduction zone located off the east coast of the North Island (Wallace et al. 2014) and South Island's Alpine Fault.

The last moderate-to-strong earthquake felt in the Wellington Region was the Mw 7.8 2016 Kaikōura earthquake (Orchiston et al. 2018), caused by the rupture of multiple faults, with its epicenter near the rural town of Waiau in the upper South Island (Kaiser et al. 2017; Robinson et al. 2011). This earthquake caused significant damage to low- and high-rise buildings in the upper South Island and Wellington Region, including residential properties (Stevenson et al. 2017). Before that, in 2013, the M 6.5 Seddon/Cook Strait (50 km from Wellington) and M 6.6 Lake Grassmere (80 km from Wellington) doublet earthquakes (Holden et al. 2013) caused \$7 million of damage to residential properties (EQC 2015).

Given that there is a high probability of a major earthquake impacting Wellington in the near future, earthquake preparedness is important for reducing losses (Johnston et al. 2013; McClure et al. 2015). Indeed, international agreements such as the Sendai Framework [Framework and United Nations Economic Commission for Europe (UNECE)] and the Aotearoa National Disaster Resilience strategy (Minister of Civil Defence & New Zealand Government 2019) encourage the management of disaster risk, implementation of risk reduction initiatives, and enhancement of disaster preparedness. Unfortunately, research has shown that Wellingtonians are relatively unprepared for such a major event (Johnston et al. 2013).

In terms of preparedness, more focus has been given to survival actions (e.g., collecting survival items such as food and water), which help immediately after an event, rather than mitigation actions, which prevent harm and reduce loss (Russell et al. 1995). Building strengthening, a mitigation action, aims to better prepare

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Note. This manuscript was submitted on November 10, 2021; approved on August 7, 2022; published online on December 9, 2022. Discussion period open until May 9, 2023; separate discussions must be submitted for individual papers. This paper is part of the *Natural Hazards Review*, © ASCE, ISSN 1527-6988.

a building to face major earthquakes while keeping as much of the building intact and original as possible. By undertaking a range of strengthening solutions in particular areas (e.g., strengthening foundations or replacing old gypsum or cladding), damage can be significantly reduced (FEMA 2012a). However, some types of structural strengthening can be expensive, and people tend to prioritize their actions depending on costs. For example, a study carried out in Wellington identified that the cost of undertaking actions affected households' decisions, so survival actions were more likely to be undertaken than mitigation actions because they are more economically accessible (McClure et al. 2015).

A variety of legislation, policies and educational campaigns have been put into practice to address earthquake risk reduction in New Zealand, such as the Building Act (2004), the Be Prepared (EQC 2020) campaign, and Strengthening your Home by the Wellington City Council (2020). Although these all seek to enforce or encourage the structural upgrade of existing buildings that were built under prior versions of New Zealand design codes, the strategies target different group holders. The participation and inclusion of different groups in the policy-/campaign-making process has been identified as one of the factors influencing policy enactment and voluntary implementation (Olshansky 2005; Tanner et al. 2020). However, research has shown that there has been not much participation of different groups and stakeholders (Olshansky 2005; Tanner et al. 2020), mainly because the low probability of occurrence of earthquake events discourages participation (Kunreuther and Kleffner 1992). Thus, there is a need to continue to encourage engagement of stakeholders, including the public, in technical and preparedness decisions to build resilient communities (Jennings 2015; Tanner et al. 2020).

Engineering studies have mentioned the need to meet societal demands of damage expectations and housing performance for major earthquakes (Takagia and Wadab 2019; Tanner et al. 2020); however, they do not refer to any systematic analysis examining such societal demands, nor have they investigated interactions of this with voluntary seismic strengthening (Pampanin 2012; Takagia and Wadab 2019). Most of the available literature with regard to building strengthening targeted high-rise and heritage buildings (Egbelakin et al. 2014; McClure et al. 2015), leaving a research gap in understanding how to motivate structural preparedness in residential low-rise buildings, which have to be voluntarily strengthened by occupants. In this study, we explore how we can encourage people, in this case homeowners, to undertake structural strengthening, and consider how expectations of damage and performance for future earthquakes influence this process. Homeowners were targeted because renters might be unable to adopt structural actions or might be living in the property temporarily.

## Preparedness Theories and the Role of Outcome Expectancy

A number of theories attempt to unpack the factors that influence preparedness actions taken before, during, and after an earthquake event (Paton 2019), such as the Person-relative-to-Event (PrE) model, Protection Motivation Theory (PMT) (Mulilis and Duval 1995; Rogers 1975; Tanner et al. 1989) and Community Engagement Theory (CET) (Paton 2013). Most studies have focused on a number of factors that influence survival preparedness rather than mitigation actions (i.e., building strengthening) (Lindell and Perry 2012; Rüstemli and Karanci 1999; Şakioroğlu 2011). Although these theories have identified a number of factors at play in the preparedness process, one common aspect relates to the importance of outcome expectancy.

Outcome expectancy (also known as response efficacy) is the perception of whether personal actions will effectively mitigate or reduce a problem, e.g., "I can deal with hazards and as a result there will be a good outcome" (Becker et al. 2011, 2015). Authors on disaster preparedness have shown that outcome expectancy predicts action coping, which is in turn linked to earthquake preparedness behavior (Crozier et al. 2006; Paton et al. 2005; Şakioroğlu 2011). Another similar concept, instrumental attitudes, has also been shown to relate to preparedness for natural hazards in Wellington, New Zealand (Vinnell et al. 2021). An individual's beliefs about the outcome of preparing can be positive (i.e., preparing will reduce damage from a natural hazard event) or negative (i.e., impacts will be too severe to mitigate). If people perceive a hazard as insurmountable, even if they are motivated, they may not develop intentions to prepare (negative outcome expectancy) (Paton 2003). Negative outcome expectancy is similar conceptually to fatalism, which is the belief that events like earthquakes are too destructive for damage to be prevented (McClure et al. 2007a). These beliefs can be reduced by showing distinctive, rather than general widespread, damage (McClure et al. 2001).

Outcome expectancy beliefs interact with a variety of other factors including social factors (e.g., community participation), perception of risk, and previous experiences (Rüstemli and Karanci 1999). Community participation, for example, can help develop positive outcome expectancy by providing a forum for individuals to interact with others and discuss hazard-related issues, and come up with solutions to those issues (action coping) (Paton et al. 2005). Individuals anticipating property damage (i.e., perception of risk or positive anxiety) are more likely to perform behaviors specifically aimed at reducing that damage (Ge et al. 2011; Paton et al. 2005; Scovell et al. 2020). A positive outcome can also come from an event-related factor of past earthquake experience (Lindell and Whitney 2000; Paton et al. 2005; Şakioroğlu 2011). Interactions can occur between both prior earthquake experience, which may be constituted by various types of experiences (e.g., personal experience, observed experience, vicarious experience) (Becker et al. 2017), and outcome expectancy beliefs, which influence behavioral responses to seismic hazard (Lindell and Whitney 2000; Şakioroğlu 2011; Weinstein 1989). Although the literature has consistently shown that perceptions of hazard are not usually directly correlated with preparedness adoption, we know that risk perception can affect the preparedness process indirectly via factors like experience and outcome expectancy (Lindell and Perry 2000; Lindell and Prater 2002; Paton et al. 2005). The importance of outcome expectancy for motivating preparedness has been demonstrated for other hazards [e.g., hurricanes (Demuth et al. 2016)].

## Expectations of Building Damage

Expectations of damage before and after structurally strengthening a building can be understood as outcome expectancy. The extent to which people think that strengthening will reduce damage to buildings in the event of an earthquake represents positive outcome expectancy. From an engineering perspective, building strengthening should align with current seismic standards which generally aim for life safety (FEMA 2012a, b; King 1999; NZSEE 2017). That is, buildings are designed to reduce the likelihood of fatalities. Structural safety can be achieved through building legislation, standards, and codes, which can apply to both new buildings and the retrofit of existing buildings that are earthquake-prone by controlling damage and preventing collapse (Ghobarah 2001; Tanner et al. 2020).

Observations of damage after major earthquakes generally align with the design philosophy of international standards, which aim to avoid building collapse and protect the life of building users.

However, economic losses have been significant. For instance, the cost of repairing and replacing damaged residential houses exceeded NZ\$10 billion after the February 22, 2011, Christchurch, New Zealand, earthquake (Thomas and Shelton 2012). It was suggested that housing should not only be engineered for life safety but should also be of a standard where it is unlikely to require significant repairs, thus limiting losses and ensuring housing remains livable and functional (Kirkham et al. 2014; Todd et al. 1994). Questions about whether the life safety objectives used in codes around the world are adequate or appropriate have arisen (Porter 2021; Tanner et al. 2020).

Even if life safety is achieved, the gap between no damage (i.e., fully operational or operational and minor damage or disruption) and life safety (i.e., moderate damage to extensive damage) might be too large, and the gap between life safety and collapse is too small (Priestly 2000). Although the design of new buildings seeks to satisfy the best standards, retrofitting old buildings, which were generally designed with poorer design procedures, aims to bring them up to current standards, which in this case would be up to life safety (FEMA2012b; FEMA 2012a; King 1999; NZSEE 2017). However, owners are generally not aware of what design codes aim for (Porter 2021), and when it comes to voluntary building strengthening, they might not fully understand the benefits or outcomes of such strengthening. This might result in negative outcome expectancy affecting not only their own perception but also the general public opinion toward building strengthening.

In New Zealand, the government enacted legislation in the Building Act (2004) to reduce seismic damage from earthquake-prone buildings (EPBs). The legislation seeks to strengthen EPBs up to current seismic standards [known as New Building Standard (NBS)]. However, after the Mw 7.8 2016 Kaikōura earthquake, judgements of the efficacy of strengthening EPBs and support for the legislation decreased, likely because several high-profile new buildings (which were out of the EPB policy scope because they were considered already up to standard) were damaged to the extent of being unusable whereas older buildings overall fared well (Vinnell et al. 2019a). However, the newer buildings that failed did not lead to any fatalities and therefore satisfied life safety as intended. This event may have altered public perceptions and, therefore, suggests that Wellington homeowners may not widely understand the focus on life safety of current standards.

People's beliefs about building performance (i.e., outcome expectancy particularly of strengthening of multistory buildings) were affected by the damage they saw. People who attribute earthquake damage to poor seismic design have been shown to believe that damage, although unavoidable, could be reduced substantially (Egbelakin et al. 2011a; McClure et al. 2007b). If they thought building damage was due to structural defects (that could be fixed) rather than the earthquake itself, it increased their outcome expectancy for strengthening. These findings support the suggestions made previously that if people see a new building damaged, it has the potential to negatively influence their belief that strengthening will lead to a positive outcome. It is also critical to have a consensus on the appropriate strengthening solutions. Egbelakin and Wilkinson (2010) observed that disparities among consultant engineers when proposing strengthening solutions aggravated the mistrust in proposed strengthening and professionals.

As highlighted in the examples given previously, having prior earthquake experience can motivate preparation for future events by seeing the benefit of strengthening, but also can act as an inhibitor. By disclosing causes of observed damage, current seismic vulnerability of existing buildings, and clear objectives of building strengthening, seismic hazard education can be enabled (McClure et al. 2007b), resulting in positive outcome expectancy of building

strengthening. Provision of information of potential outcomes of building performance during earthquakes can play a crucial role, especially when there is a lack of earthquake experience (Becker et al. 2017). Understanding what to expect in major earthquake events and what can be done to strengthen properties can motivate preparedness. In other words, a positive outcome expectancy about strengthening buildings can promote the adoption of strengthening mitigations (Egbelakin et al. 2011a).

### Gaps in Research

The preceding literature review highlighted several topics that need to be considered in researching homeowners' outcome expectancy of structural strengthening. First, a significant gap in the existing research has been a tendency to focus on studying appraisal factors, such as outcome expectancy, in the context of survival preparedness rather than mitigation actions (i.e., building strengthening) (Lindell and Perry 2012; Rüstemli and Karanci 1999; Şakioroğlu 2011). Therefore, clarification is required on how outcome expectancy works in terms of voluntary structural strengthening in residential settings.

Second, there has been a tendency to focus on factors influencing preparedness but not on how these factors interact with each other to influence preparedness (Paton 2019), particularly in terms of building strengthening. One interactive factor includes previous experience and its effects on expectations of future damage to buildings, and outcome expectancy for structural strengthening.

Third, expectations of damage from an engineering point of view do not exceed life safety (i.e., moderate to extensive damage) (Priestly 2000). However, questions about whether other people expect a similar outcome after a major earthquake must be answered. By including different stakeholders in the analysis, different perspectives can be disclosed, which may change the approach of current policies or campaigns seeking to motivate people to strengthening their properties. In particular, understanding people's expectations is useful for knowing what performance people expect from their houses after a future earthquake (e.g., life safety versus full functionality), and whether people have particular outcome expectancy beliefs about structural strengthening for that context.

Finally, in a New Zealand context, most of the available literature has focused on EPBs, excluding residential low-rise dwellings, which must be strengthened voluntarily by owners. Generally, policies and standards for strengthening EPBs are well-known by stakeholders of multistory buildings, and there are clear procedures to follow, such as contacting an engineering consultant company to carry out the potential needed work. However, strengthening of residential houses (i.e., smaller buildings), which are outside of EPB provisions, is different. Voluntary strengthening can be carried out depending on the owner's knowledge, e.g., they might know a builder, contact an engineer, or look for information online. Given the voluntary and fluid nature of strengthening residential low-rise houses, there is a need to understand owners' perceptions of strengthening, and the information they might or might not have that can result in preparing (or not preparing) their house.

By studying people's expectations of future earthquake damage (including how these fit with current seismic standards), their outcome expectancy of structural strengthening for that damage, how prior experience might influence outcome expectancy, and the information owners have about structural strengthening, we can help inform structural performance objectives. These might need to change if societal demands turn out to be higher. We also can identify relevant interventions—different pathways toward strengthening adoption—that both improve housing performance in an earthquake and satisfy community expectations.

## Method

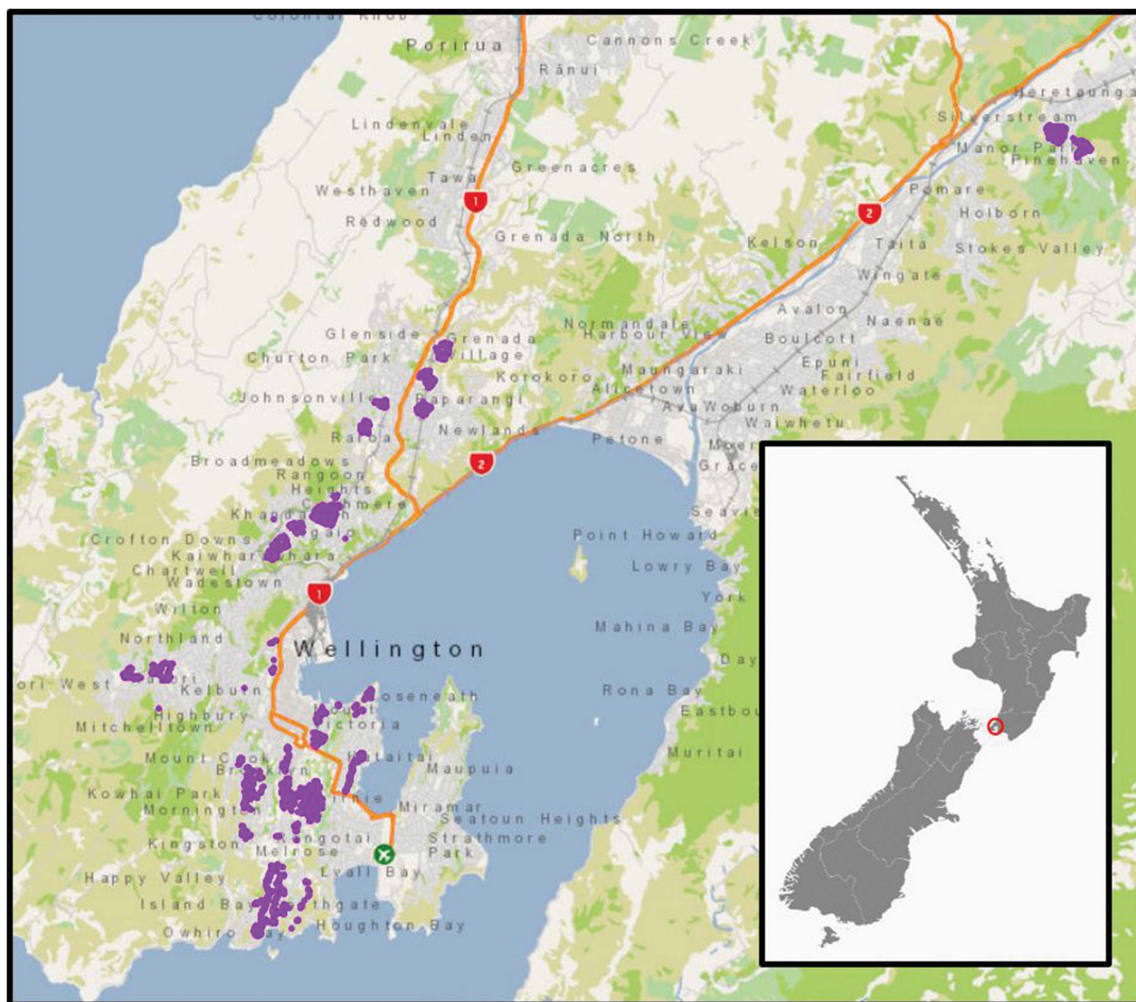
This study targeted homeowners of wooden-framed houses in the Wellington region. Wooden-framed houses are one of the oldest construction types used in many parts of the world, making up more than 80% of its residential housing stock (Miskell 2008). In Wellington, early records show that dwellings constructed in accordance with European standards were mainly built using masonry and timber similar to European houses of colonization times. The first major earthquake to test houses occurred on October 16, 1848, near Wellington, which caused significant damage to masonry structures. Consequently, after this event, the majority of houses were built in timber. A similar poor performance of masonry and the observation that timber dwellings performed well during earthquakes was also noted after the 1855 Wairarapa and 1931 Napier earthquakes (Cooney 1979).

In terms of earthquake provision or recommendations for wooden houses, the first adopted regulations came out in 1924, which was followed by various updates until the first introduction of timber structures in the NZS 95 (NZS 1936) the first New Zealand seismic code, as an amendment in 1944 (Beattie and Thurston 2006). After several updates in the NZS 95, in 1978 the first official publication of the NZS 3604 (NZS 2011), a code of practice for light timber-framed buildings, came out. NZS 3604 allowed design of timber houses

without using technical engineering design, mainly used by builders; up to 2022, NZS 3604 has been reviewed and updated several times (i.e., 1984, 1990, and 1999). The long-term use of timber for construction of New Zealand housing and the several updates on timber design codes resulted in the need of structurally retrofitting existing—old—houses up to current standards.

In addition, the Wellington region presents topographical features and geographic occurrences such as steep slopes where many houses are located (Miskell 2008). After significant earthquakes in the United States and New Zealand, it has been observed that houses located on slopes suffered more damage than similar ones in flat areas (Thomas and Shelton 2012; Todd et al. 1994). Prior research has shown that around half of the houses in Wellington could suffer severe damage after a magnitude 7.5 earthquake (Thomas and Finc 2017). The combination of hilly houses and high seismic activity dramatically influence the dwellings' vulnerability to earthquakes, and hence the necessity to implement preparedness actions for wooden structures.

To understand expectations of future earthquake damage and performance for these houses, and what might influence structural strengthening preparations, 3,000 questionnaires were distributed in the Wellington Region during January and February 2020 (Fig. 1). This survey had a response rate of 19%. We entered the data into the SPSS version 26 software program and performed



**Fig. 1.** Study area and distributed questionnaires: Wellington, New Zealand. [Reprinted from Toitū Te Whenua Land Information New Zealand 2020, under Creative Commons-BY-4.0 license (<https://creativecommons.org/licenses/by/4.0/>); base map © MapTiler © OpenStreetMap contributors.]

**Table 1.** Scale of damage and respective observations

Level of damage	Observations
Undamaged	No damage at all
Minimal	Internal hairline cracks in wall, which can be solved by painting over
Minor	Cladding or stucco fell, or some windows broken
Moderate	Some walls replaced or fixed up. The chimney fell. Cracks in floor or damage to foundations
Major	The houses would not collapse but it would be inhabitable
Extreme	Total collapse

basic statistical frequency analyses alongside *t*-tests and chi-square tests. The questionnaire was conducted in accordance with the University of Auckland Human Participants Ethics Committee (UAHPEC Reference No. 023962).

## Measures

Participants were asked questions grouped in three sections: personal prior earthquake experience, structural strengthening and anticipated damage, and structural features of their houses. In this paper, results of the first and second sections are presented. In order to capture homeowners' perceptions of damage to their houses during previous major earthquakes, six levels of damage were presented to participants (1= undamaged; 2 = minimal; 3 = minor; 4 = moderate; 5 = major; and 6 = extreme). Details of observed damage for each level are presented in Table 1. This scale was developed based on the intensity levels of the New Zealand Modified Mercalli Intensity scale (MMI); the life safety level of damage fits within the category of major damage (Level 5). MMI is well-known as one of the most suitable approaches for measuring the intensity of earthquakes (Dowrick et al. 2008). The same scale was used by Miranda et al. (2021). However, Miranda et al. (2021) used the scale to measure different levels of prior earthquake damage and whether people have prepared for future major earthquakes, whereas the study presented herein will use damage experience as a factor influencing expectations of damage.

In Section 1 of the questionnaire, participants were asked to indicate previous observed damage to their houses from earthquakes by using the damage scale. Additionally, participants were asked to indicate what earthquake caused that damage. The multichoice question allowed participants to pick more than one option among 2016 Kaikōura, 2013 Seddon and/or Cook Strait, 2011 Christchurch, 2013 Lake Grassmere, 2010 Darfield, Other, and Not Applicable. In the second section, participants were asked if they were aware of the possibility of strengthening their houses. Answers to this question were used to divide the sample into two subgroups for analysis: aware participants, and not-aware participants. Participants were then asked whether they had applied any strengthening to their houses. This allowed us to further subclassify the sample into three subgroups: prepared participants (aware of strengthening and used strengthening); unprepared aware participants (aware of strengthening but have not done anything); and unprepared not-aware participants (not aware of strengthening so strengthening has not been used). We therefore also had a subgroup of unprepared participants, which includes unprepared aware participants and unprepared not-aware participants.

In order to assess outcome expectancy of structural strengthening, our key study variable, prepared participants were asked to select one level of damage from the damage scale that they think

would have happened before undertaking strengthening for a future hypothetical MM8 earthquake (described as involving difficulty standing, general alarm causing panic, and the whole town feeling the shaking). Then, prepared participants were asked to indicate the level of damage to their house during the same earthquake but after applying strengthening (i.e., the current situation for prepared participants).

Similar questions were asked to unprepared participants. First, they were asked what level of damage they thought would happen to their houses during a hypothetical MM8 earthquake. Then, unprepared participants were asked to imagine that they had undertaken strengthening and to indicate the expected level of damage to their houses during the same earthquake but after applying strengthening.

In order to understand the levels of confidence in implemented strengthening, prepared participants were asked to indicate if they thought they would need to undertake more strengthening to ensure minimal damage to their house. This question used a 5-point scale with responses anchored by 1 (definitely yes) and 5 (definitely not), and 3 (unsure) as the midpoint. Because unprepared participants had not undertaken any structural strengthening, they were asked to indicate the main reasons for not using strengthening. Seven reasons were presented (i.e., I think structural actions are too expensive, I do not spend much time in my house, I don't trust the proposed methods, I am unsure about the cost/benefit, I did not know it was possible to improve the structural performance of my house, I have insurance which will cover any structural damage to my house, and I do not have a clear idea of what to do) as well as an Other option, which allowed specification of other reasons. Participants could tick more than one of these presented reasons.

Next, prepared participants were asked to indicate where they had obtained information about strengthening. Similarly, unprepared participants were asked to indicate where they would look for information. Multiple options were given to both subgroups: friends, council guidelines, Earthquake Commission (EQC), news, social media, expert engineering consultant, builders, or others. Then, unprepared participants indicated whether they would consider undertaking strengthening now that they are aware of the possibility of undertaking structural strengthening. This item used a 5-point scale with responses anchored by 1 (definitely yes) and 5 (definitely not), and 3 (unsure) as the midpoint. To finish, all participants were asked to indicate if they would feel safe at home during an MM8 earthquake by selecting one number between 0 (extremely safe) and 5 (extremely unsafe).

## Results

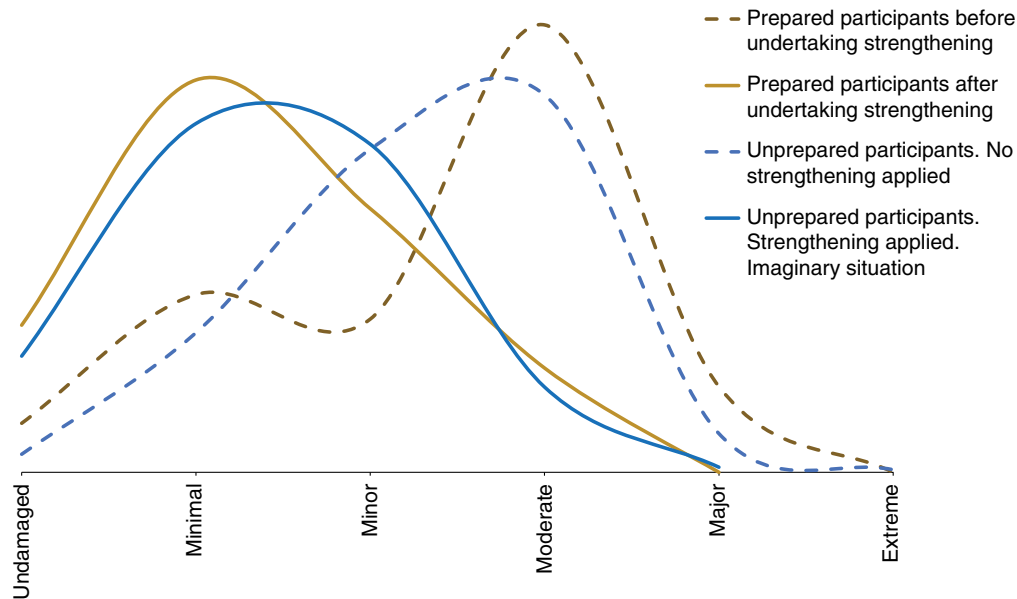
### Expected Damage and Housing Performance

The question on perceptions of earthquake damage was scored from 1 to 6 (i.e., undamaged to extreme damage), and a mean damage value was calculated. For prepared participants, the mean damage predicted for future earthquakes by homeowners before undertaking strengthening, and the mean damage predicted after undertaking strengthening were compared using a paired samples *t*-test. The paired sample *t*-test revealed that prepared participants expected a significantly worse seismic performance of their house without the strengthening they had implemented, expecting on average between moderate (4) and minor (3) damage, compared with after strengthening, expecting between minor (3) and minimal (2) damage (Table 2).

Similar responses were given by unprepared participants (including aware and not-aware participants), who expected a

**Table 2.** Paired samples *t*-test results comparing prediction of damage by prepared and unprepared participants

Participants	Strengthening	Mean	Standard deviation	<i>t</i> -test
Prepared	Before	3.38	1.05	$t(152) = 15.7, p < 0.05$
	After	2.33	1.88	
Unprepared	Without	3.35	0.87	$t(403) = 26.6, p \leq 0.05$
	Imaginary situation	2.44	0.86	

**Fig. 2.** Distribution of prepared participants based on expectations of damage to their houses before and after strengthening; and unprepared participants without strengthening and after applying strengthening (imaginary).**Table 3.** Outcome efficacy for prepared, aware but unprepared, and not-aware and unprepared participants

Participants	Outcome expectancy	Standard deviation	<i>t</i> -test	<i>t</i> -test
Prepared	1.04	0.82	$t(296.14) = 2.26, p < 0.05$	—
Aware but unprepared	0.82	0.65	—	$t(376.13) = 3.25, p < 0.05$
Not aware and unprepared	1.04	0.73	—	—

Note: Question was scored from 1 to 6 (i.e., undamaged to extreme damage).

worse structural seismic performance of their houses without strengthening, between moderate (4) and minor (3), than after imagining undertaking strengthening, minor (3) and minimal (2) (Table 2). Fig. 2 illustrates the distribution of expectations of damage among prepared and unprepared participants.

The results suggest that strengthening can change the perception of damage in a future major earthquake regardless of whether the strengthening has actually been undertaken. Interestingly, however, those who have actually undertaken strengthening appeared to see more benefit in strengthening than those who had not prepared (demonstrated by the greater difference in the before and after means in the former group). We therefore tested this apparent difference statistically.

Outcome expectancy was calculated as the difference between expected performance before and after strengthening for prepared participants as well as aware but unprepared participants (Table 3). This variable, therefore, represents the extent to which participants think that strengthening will reduce damage to their house in the event of an earthquake; a higher score represents stronger

perceptions of outcome expectancy. An independent sample *t*-test to compare the outcome efficacy variable between prepared participants and aware but unprepared participants, revealed that the mean score of outcome expectancy among prepared participants significantly differed from the mean score for aware but unprepared participants. Although both groups demonstrated positive, rather than negative, outcome expectancy, this finding suggests that prepared participants think that strengthening is more effective in improving the seismic performance of their houses than aware but unprepared participants (Table 3).

An independent sample *t*-test to compare the outcome efficacy variable between aware but unprepared participants and not-aware and unprepared participants revealed that not-aware and unprepared participants think that strengthening would reduce more damage to their house in the event of an earthquake than aware but unprepared participants, equal variances not assumed (Table 3).

Interestingly, outcome expectancy was similar between those who have prepared and those who are unaware of strengthening techniques. It is possible that those who are aware of strengthening

**Table 4.** Number and percentage of participants who selected a level of damage observed during the earthquake/s they identified in Table 2

Level of observed damage	Count, <i>n</i>	Percentage
Undamaged	293	51.9
Minimal	239	42.3
Minor	11	1.9
Moderate	9	1.6
Major	1	0.2
Not applicable	11	1.9
Missing	1	0.2
Total	565	100.0

Note: A not applicable option was given to those that did not perceive damage.

but not implemented any changes have received information that led to them having a lower outcome expectancy. This assumption should be explored further to understand how people are being made aware of strengthening so that these information sources can be improved.

### Outcome Expectancy and Prior Earthquake Experience

Both the ranked question about previous earthquake damage experience and the question on perceptions of earthquake damage had the same level of damage, which allowed the calculation of a mean damage value scored from 1 to 6 (i.e., undamaged to extreme damage). A paired sample *t*-test to compare current expectations of prepared participants and previous damage experience, revealed that prepared participants expect more damage in a future major earthquake [ $M = 2.35$  and standard deviation ( $SD$ ) = 0.89] than the damage observed in previous earthquakes ( $M = 1.61$  and  $SD = 0.78$ ),  $t(145) = 8.33$ , and  $p < 0.05$  (Fig. 2). This might be due to the low score associated with the question of previous earthquake damage experience (Table 4). Although participants were asked to select what specific earthquake caused the damage indicated in Table 5, more participants named earthquakes causing general disruption than had indicated that they had experienced damage to their house in the last seismic event (the questionnaire is provided in the Supplemental Materials). Some participants reported multiple earthquakes in which they had experienced damage; it is possible that these participants were thinking about the earlier question that asked them about a range of different types of damage they had perceived and were answering in line with those experiences. This however does not affect the fact that most of the participants had experienced the 2016 Kaikōura earthquake. Similar results were found for unprepared participants, who expect more damage in a future major earthquake ( $M = 3.32$  and

**Table 5.** Number of participants who selected one or more earthquakes responsible for the damage to their house

Earthquake that caused damage	Count, <i>n</i>	Percentage
2016 Kaikōura	341	72.4
2013 Seddon and/or Cook Strait	85	18.0
2011 Christchurch	13	2.8
2013 Lake Grassmere	16	3.4
2010 Darfield	6	1.3
Other earthquakes	10	2.1

Note: The multichoice question allowed participants to pick more than one option. A Not Applicable option was given to those that did not perceive damage.

**Table 6.** Outcome expectancy means values for participants that have not experienced damage or have experienced minimal damage to their houses

Participants	Outcome expectancy	
	<i>M</i>	<i>SD</i>
Experienced no damage to their houses in previous earthquakes	0.92	0.83
Experienced minimal damage to their houses in previous earthquakes	0.96	0.71

$SD = 0.87$ ) than the damage observed in previous earthquakes ( $M = 1.63$ ,  $SD = 1.07$ ),  $t(345) = 24.33$ , and  $p < 0.05$ .

Because the vast majority of participants classified observed damage to their houses after previous seismic events into mainly two levels of damage (undamaged and minimal) (Table 4), a new dichotomous independent variable was created in order to carry out a two-way ANOVA using only these two levels (Table 6), along with another independent variable related to the use and nonuse of strengthening (i.e., prepared participants and aware but unprepared participants). The outcome expectancy variable was the dependent variable.

There was not a significant interaction of effects of preparation and levels of damage experience on outcome expectancy,  $F(1,333) = 0.03$  and  $p = 0.863$ . That is, the difference in outcome expectancy between prepared participants and aware but unprepared participants is likely not due to either group having more or less experience of previous damage. There was no main effect of previous damage on outcome expectancy (Table 6).

Because experience has been shown to influence the use of structural strengthening (Miranda et al. 2021), a two-way analysis of covariance (ANCOVA) was carried out including damage earthquake experience as a covariable. The pattern of results did not differ from the results of the two-way ANOVA, suggesting that the lack of relationships among previous observed damage, use of strengthening, and outcome expectancy was not because of effects of previous earthquake experience,  $F(1,202.69) = 0.25$ , and  $p = 0.53$ .

### Reasons for Not Strengthening

The question measuring levels of confidence in implemented strengthening was scored from 1 (definitely yes, I would need to undertake more strengthening) to 5 (definitely not, I would not need to undertake more strengthening), and mean values were calculated. Prepared participants reported being relatively unsure about whether they need to undertake extra strengthening to ensure minimal damage to their house in a future MM8 earthquake,  $M = 3.11$  and  $SD = 1.35$ . This suggests that some homeowners are not sure about how much their house's seismic performance would improve after undertaking further strengthening. This is supported by an independent samples *t*-test demonstrating that there was no statistically significant effect on feelings of safety for prepared participants and unprepared participants,  $t(524) = 1.26$  and  $p = 0.21$  (Table 7). Similar levels of feeling safe at home during an MM8 earthquake for prepared participants and unprepared participants suggests that prepared participants might not fully understand the benefits of undertaking structural strengthening.

Further, unprepared participants identified the main reasons for not undertaking strengthening. Both aware but unprepared participants and not-aware and unprepared participants reported that the main reason for not taking strengthening actions was uncertainty about the cost/benefit. However, not-aware and unprepared

**Table 7.** Levels of safety mean values for prepared participants and unprepared participants

Safety	<i>n</i>	<i>M</i>	<i>SD</i>
Prepared participants	156	2.44	0.94
Unprepared participants	370	2.55	0.90

participants were much more likely to not trust in the proposed strengthening methods, probably because they did not know about them (Fig. 3). The question assessing the likelihood of undertaking strengthening was evaluated by an independent sample *t*-test (scored from 1 to 5, where 1 = definitely yes and 5 = definitely not). Aware but unprepared participants ( $M = 3.04$  and  $SD = 1.22$ ) were significantly less likely to contemplate using strengthening than not-aware and unprepared participants ( $M = 2.61$  and  $SD = 1.09$ ),  $t(303) = 3.21$ , and  $p < 0.05$ . This finding suggests that the information that aware but unprepared participants have about strengthening inhibited, rather than motivated, behavioral uptake.

Finally, participants indicated where they had obtained information about strengthening (prepared participants) or where they would look for further information (unprepared participants). By far, the most common source prepared participants indicated that they acquired information from was builders [Fig. 4(a)]. On the other hand, unprepared participants showed a preference toward information sourced from the Wellington City Council or EQC rather than builders. However, unprepared participants, including aware and not-aware participants [Fig. 4(b)] had similar preferences including Wellington City Council, EQC, and engineers or builders.

Finally, prepared and unprepared participants were asked if they trust the information about strengthening techniques provided by the City Council, EQC, engineers, and builders. This item used a 5-point scale with responses anchored by 1 (strongly agree) and 5 (strongly disagree). Whereas prepared and unprepared participants had similar levels of trust toward the information provided by the EQC [ $t(557) = 1.08$  and  $p = 0.073$ ] and engineering consultant companies [ $t(554) = 0.84$  and  $p = 0.4$ ], prepared participants had higher levels of trust toward the information provided

by the City Council [ $t(561) = 2.37$  and  $p < 0.05$ ] and builders [ $t(553) = 3.35$  and  $p < 0.05$ ] than unprepared participants (Table 8).

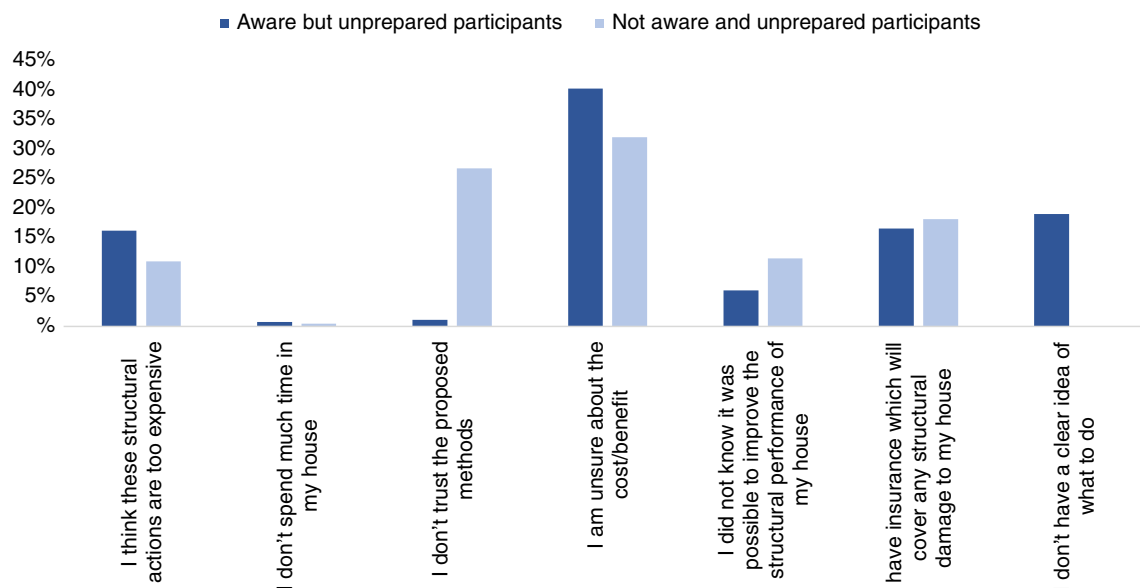
## Discussion

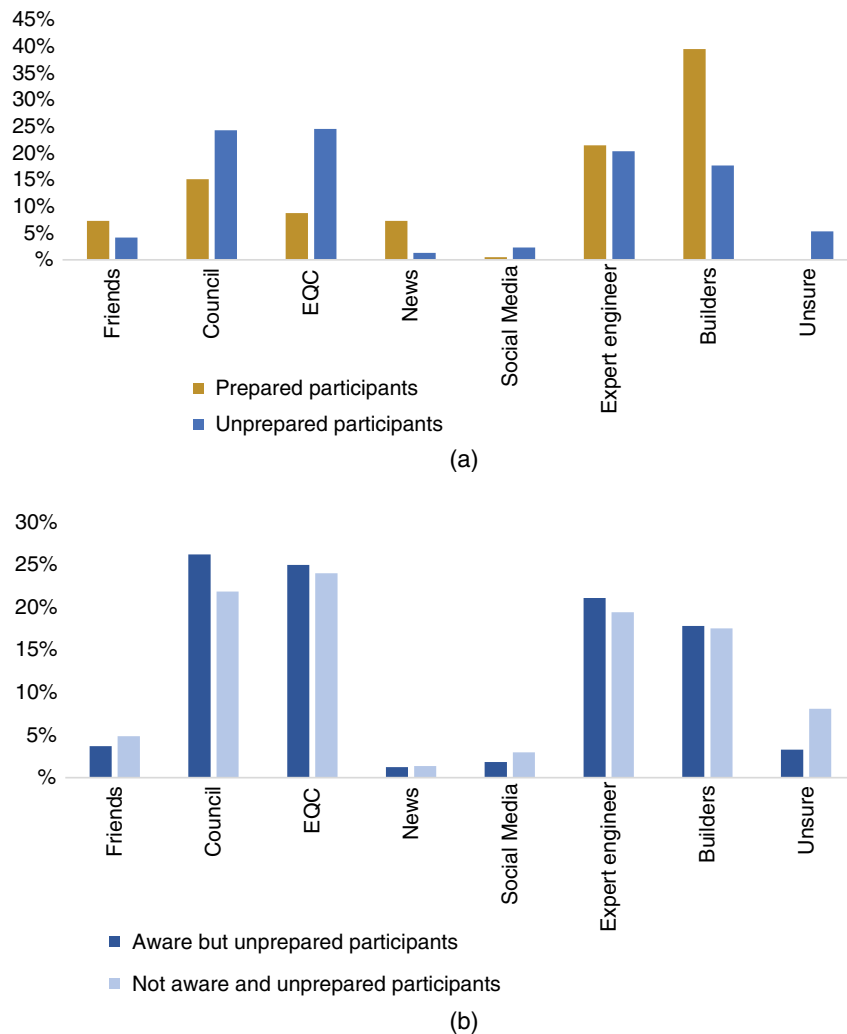
### Conceptual Framework

By integrating the results presented herein and based on similar frameworks available in the literature (Egbelakin et al. 2011b; Lindell and Perry 2012; Paton et al. 2005), we developed a conceptual framework to visualize how voluntary seismic strengthening can be motivated and adopted (Fig. 5). The framework shows that the final steps (decision and adoption) before undertaking mitigation are, positively or negatively, influenced by outcome expectancy and prior experience. Both influence each other but also are influenced by available information. Further explanation of our framework is outlined in the following subsections.

### Outcome Expectancy of Strengthening

The statistically significant differences between perceptions of damage before and after anticipated and actual structural strengthening indicates that positive outcome expectancy is an important component of the structural preparedness process. On average, participants predicted future damage for a hypothetical MM8 earthquake between moderate (4) and minor (3) before strengthening, and between minor (3) and minimal (2) after strengthening. However, participants that had adopted strengthening already (prepared participants) showed higher levels of outcome expectancy than aware but unprepared participants. This aligns with prior research that proposes that actions are more likely to be taken if people believe that these preparations will prevent damage (i.e., positive outcome expectancy) (Şakioroğlu 2011). Having a positive outcome expectancy would allow people to move to the intention to prepare phase (Fig. 5), which later has to be further motivated by information providers (e.g., EQC, Wellington City Council, builders, or engineers) to achieve final adoption. Also, because beliefs about damage mitigation have been associated with education and

**Fig. 3.** Reason for not undertaking strengthening for both aware but unprepared participants and not-aware and unprepared participants.



**Fig. 4.** Potential sources of strengthening information for (a) prepared and unprepared participants; and (b) aware and not-aware unprepared participants.

**Table 8.** Trust toward sources of information by prepared and unprepared participants

Trust the information about strengthening techniques provided by different sources	Participants	<i>n</i>	<i>M</i>	<i>SD</i>
City Council	Prepared participants	153	2.22	1.03
	Unprepared participants	410	2.44	0.98
Earthquake Commission (EQC)	Prepared participants	151	2.09	0.95
	Unprepared participants	408	2.25	0.95
Engineering consultant companies	Prepared participants	151	1.81	1.79
	Unprepared participants	405	1.96	1.97
Builders	Prepared participants	151	2.77	0.95
	Unprepared participants	404	3.09	1.01

Note: Five-point scale of 1 = strongly agree to 5 = strongly disagree.

knowledge on proposed mitigation (Rüstemli and Karanci 1999), we suggest that it is possible that prepared participants showed more positive outcome expectancy because they were more informed about strengthening than those who said they were aware of the possibility but had not undertaken any. Here, information providers and social factors play a key role in motivating final adoption. Importantly, our study has demonstrated a relationship

between outcome expectancy and mitigation preparation actions, providing a useful addition to the literature, which tends to focus on survival actions.

Although prior research has reported that people who anticipate damage from a future event are more likely to do something to be better prepared (Ge et al. 2011; Scovell et al. 2020), this study showed that not all participants who anticipate damage to their

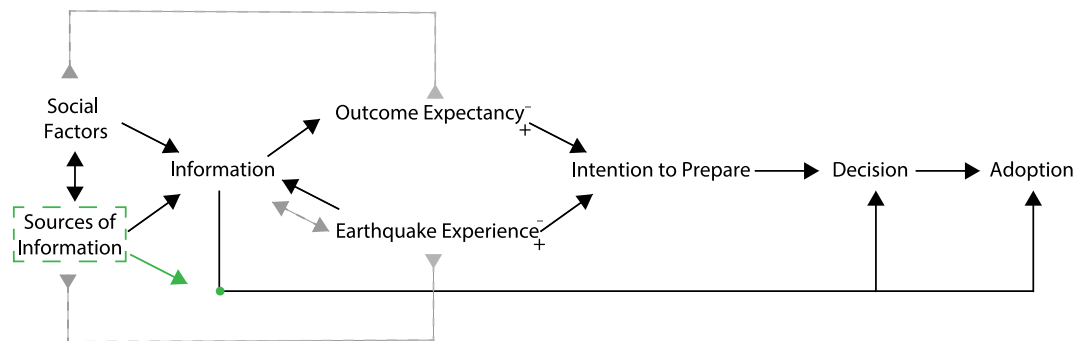


Fig. 5. Conceptual framework on voluntary seismic strengthening in residential settings.

houses have undertaken strengthening. Aware but unprepared participants showed a positive outcome expectancy of strengthening but have not completed strengthening of their houses. This is further compounded by the fact that aware but unprepared participants are less likely to consider using strengthening than not-aware and unprepared participants. In this case, positive outcome expectancy about damage reduction has not been enough to influence strengthening alone; other factors therefore need to be considered, such as providing people with information (Fig. 5). Although the benefits of using strengthening to reduce damage might be clear to participants, previous research suggests that it is possible that aware but unprepared participants are uncertain about the financial benefits (McClure et al. 2015). Clarification on the cost/benefits of strengthening could therefore be used to influence preparedness.

It is noteworthy that although prepared participants have higher levels of outcome expectancy, their levels of safety (i.e., how safe they would feel staying home during a major earthquake) are similar to those stated by unprepared participants. This could suggest that prepared participants are also somewhat hesitant about the beneficial outcomes of undertaking strengthening, or potentially that they perceive earthquake risk as higher. Also, prepared participants indicated that they are not sure whether they would have to undertake more strengthening to ensure an improved level of performance. This finding is different to what was found by Paton (2013) on survival actions, where it was stated that after fully implementing adjustments, people believed no further actions are required. However, survival actions should be sustained over time to be effective (Paton 2013) unlike structural strengthening, which can be taken once depending on the expected outcomes (i.e., building damage).

Regardless of the use (or not) of strengthening techniques, participants expected a seismic performance lower than Level 5, life safety (i.e., they expected a better seismic performance of their house than what the current seismic standards ensure). This is similar to results from a Ministry of Business Innovation and Employment (2021) survey on the earthquake-prone building system, which found people's expectations went beyond the EPB system's focus on managing risks to human life to include building resilience. Our survey highlights that expectations of damage of homeowners therefore do not appear to align with the objectives of current New Zealand building codes, which aim to achieve life safety. This can be aggravated by the fact that some homeowners likely undertook strengthening expecting a certain level of performance, which might not be achieved because current strengthening solutions might just aim to meet life safety standards.

Communication (e.g., among engineering, builders, and homeowners' communities) of what to expect from voluntarily preparing houses to better face major earthquakes is urgently needed so

owners can understand what life safety means, if their house currently meets that standard, and what they can do to strengthen their house to or beyond that standard. Given that houses in Wellington have seismically performed well during recent strong earthquakes—meeting the life safety criteria as there have been no fatalities—worries about economic potential losses are potentially more of a significant consideration (Schierle 2003; Thomas and Shelton 2012). These concerns can be tackled by aiming for more than life safety. In an outcome expectancy context, that means understanding some of those benefits beyond life safety (i.e., functional recovery), which can then be used to motivate structural preparedness as a way of achieving those benefits/aims/outcomes. Additionally, open communication between communities, engineers and builders would help homeowners to understand future damage and avoid once again a lack of trust in the engineering community after a major event (Egbelakin and Wilkinson 2010; McClure et al. 2007b; Vinnell et al. 2019b). Good examples where this communication happens are heritage buildings, where research has shown that heritage buildings are desired to be preserved by the community and hence they may be strengthened beyond life safety (Beaupre et al. 2014).

Because the EQC and the Wellington City Council (i.e., information providers and social factors) were selected as primary sources of information about strengthening by unprepared participants, these organizations play a critical role in advocating preparedness for future earthquakes. Their role in information provision should continue. In addition, the way homeowners of residential houses (i.e., smaller buildings) seek or receive information about strengthening is more transmitted by word of mouth rather than official policies such the one for EPBs—hence, the importance of engaging with information providers, such as builders, that can be contacted directly by homeowners. For instance, builders can be asked to carry out different work—like painting or renovations—and then they could pass on information to owners about the potential works that could be undertaken to seismically strengthen houses. As our results have shown, builders were the first source of information for prepared participants; consequently, builders could not only help with providing information but also have a direct role in the decision and adoption of strengthening because they are the ones mainly carrying out the actual work.

Trust in sources of information is crucial in building linkages between intentions to seek information and adjustment adoption (Paton et al. 2005). Unprepared participants could have been affected by an external locus of control, which makes individuals think that none of the things that they do will minimize the damaging consequences of earthquakes and hazards (Crozier et al. 2006) because they have lower levels of outcome expectancy than prepared participants. This bias can be corrected by emphasizing

the role of human decisions in limiting damage (McClure et al. 2007b). The more strongly that people believe actions will be effective, the more likely they are to take those actions (Paton et al. 2010). Thus, in earthquake preparedness training programs and communication to encourage actions such as building strengthening, information should be presented about how and why each preparation activity is effective at reducing earthquake impacts (Şakıoroğlu 2011).

The literature has demonstrated that clear information and advice from expert sources (e.g., through public education programs) can result in the adoption of a particular behavior and the outcome of increased safety because people interpret this information and its recommendations to estimate whether they expect that outcome to occur (Paton et al. 2010). Providing information based on sound risk communication may change perceptions of risk, outcome expectancy, and likelihood of a hazard occurrence (Paton et al. 2005). The strengthening reported in our study was implemented mainly by builders and engineers, highlighting that these professions play a crucial role in information dissemination and facilitation of strengthening (i.e., green path on the conceptual framework in Fig. 5). Further research should be undertaken to understand if the strengthening employed by these professionals, which seeks to bring old houses up to current standards, will meet homeowners' expectations of building performance in a future earthquake. Standardized proposed strengthening for residential houses would help to meet homeowners' expectations of damage, which is important for increasing trust toward engineering solutions and perceptions of outcome expectancy, and which in turn can motivate the use of structural strengthening.

### Outcome Expectancy and Prior Experience

Both prepared participants and aware but unprepared participants did not show different levels of outcome expectancy based on their prior experience of damage. This can be explained by the lack of significant prior experience of damage to houses, as mentioned by Miranda et al. (2021). When damage was treated as dichotomous (i.e., undamaged or minimal damage), there was also no significant difference in outcome expectancy with respect to damage experience. Consequently, we suggest that the effects of damage experience largely do not influence the outcome expectancy of structural strengthening, at least when this damage is not major.

The lack of relationship between prior experience and outcome expectancy could be explained by the time difference between data collection and the occurrence of the last major earthquake, which may have influenced earthquake-related cognitions (Rüstemli and Karanci 1999). However, homeowners expect more damage to their houses in a future major earthquake compared with what they have experienced, which suggests that they are aware of the potential occurrence of a stronger earthquake. Rüstemli and Karanci (1999) suggests that the severity of past experience may not affect how a person orients themselves both cognitively and behaviorally in respect to future hazard events. The last earthquake experienced by most participants was the Kaikōura Earthquake (2016), which resulted in no to minimal damage to residential houses in Wellington (Kaiser et al. 2017). This experience could have increased optimism bias, where participants thought a future event might produce similar benign effects and did not see a benefit from strengthening their houses (i.e., a lack of positive outcome expectancy), or normalization bias, where participants felt that the last earthquake was not too damaging resulting in beliefs of not needing to strengthen their house (Celsi et al. 2005; Spittal et al. 2005). This is in contrast with more damaging events, such as the 2010 and 2011 Canterbury

earthquakes, where preparation actions to mitigate damage increased for a short period of time after the earthquakes (McClure et al. 2013).

Given that major earthquakes may not be experienced within a person's lifetime, people may not have the opportunity to assess the effectiveness of mitigation measures for themselves (Simpson-Housley and Curtis 1983). Consequently, people rarely have any chance to gain first-hand experience of either the consequences they may encounter or the opportunity to assess the effectiveness of mitigation measures for themselves. Other sources of information should therefore be provided to homeowners to prompt preparedness (i.e., gray path on conceptual framework in Fig. 5), such as information about the benefits of strengthening houses (i.e., explaining and creating positive outcome expectancy). Greater dissemination of earthquake strengthening options and their effects on the likely seismic performance of houses is needed to not only encourage preparedness but also increase the levels of trust toward providers of information (i.e., also gray path on conceptual framework in Fig. 5). This information could increase the uptake of retrofitting and, in turn, allow homeowners to reduce costs on reparability following a catastrophic event, which is one of the objectives of building a resilient community.

### Limitations and Future Research

Although this study analyses the outcome expectancy of using strengthening solutions to better prepare houses for future major earthquakes, it does not mean that those expectations of damage are what people would like to happen to their house after an earthquake. Future research could specify the difference between those preferences and expectations of earthquake damage. Apart from that, other limitations include that the survey was conducted in the Wellington region only. Although Wellington is well known for its seismic activity, results might not be directly generalizable to other similar earthquake-prone cities. Further, contextual factors such as demographics and access to earthquake preparedness information could be considered in future research. The survey targeted only homeowners of wooden-framed houses, so other studies could examine the expectations of damage among renters or owners of different types of building, such as high-rise or masonry buildings. Finally, more systematic research could be carried out to understand what kind of strengthening has been used by homeowners, for instance follow-on interviews to better understand the reasons for preparing and not preparing.

### Conclusions

Providing people with information about the benefits and outcomes of strengthening their house will likely be beneficial in motivating the adoption of earthquake strengthening in Wellington, New Zealand. We found that prior experience of minimal damage from the 2016 Kaikōura earthquake did not influence perceptions of potential damage from future earthquakes and was not directly linked with outcome expectancy. People did, however, see the benefit of strengthening in that it would reduce future damage, and prepared participants had higher levels of positive outcome expectancy than those not prepared, indicating a role for outcome expectancy in the structural preparedness process. We also highlighted that all participants expected lower levels of damage than what is accepted by current seismic codes, namely life safety.

Discussions among the residential sector and the engineering community, including EQC, Wellington City Council, engineering consultant companies, and builders, are critical to increase levels of preparedness; further, conversations are needed to identify the

publi's preference and assumptions about structural performance targets, such as life safety or functional buildings postearthquake, articulations of the benefits of those different aspects, and the framing of preparedness information to meet those aims and benefits.

## Data Availability Statement

All data, models, and code generated or used during the study appear in the published article.

## Acknowledgments

The authors thank QuakeCoRE, a Aotearoa New Zealand Tertiary Education Commission-funded Centre, for funding and supporting the research. This is QuakeCoRE publication number 0716. We also thank research fellows at the Joint Centre for Disaster Research (JCDR) at Massey University for distributing surveys. This research was conducted in accordance with the University of Auckland Human Participants Ethics Committee (UAHPEC Reference Number 023962). We thank all participants for their support in this research.

## Supplemental Materials

The questionnaire is available online in the ASCE Library ([www.ascelibrary.org](http://www.ascelibrary.org)).

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