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ORIGINAL PAPER

Social influences on behavioural response to earthquake shaking: evidence from CCTV footage

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Abstract
Decades of research has demonstrated that people look to those around them for behavioural cues in novel or uncertain situations, including emergencies. One such context in which the role of social influence has largely not been explored is earthquake shaking. Earthquakes are sudden and extreme events which can be disconcerting for those experiencing them. Many earthquake injuries in countries such as Aotearoa New Zealand result from people either not taking the recommended protective actions (Drop, cover, and hold) or taking other actions which can increase their injury risk. While education efforts such as the annual ShakeOut earthquake drill in Aotearoa New Zealand have been shown to improve knowledge of protective actions, the rates of use of these actions in real earthquake events could be improved. Instead, people often hesitate before acting, perhaps because they are unsure of how to respond given the (relative) infrequency of earthquakes. In such situations, people might look to those around them for behavioural cues. To test this idea, we examined Closed-Circuit Television Footage from Wellington International Airport during the M7.8 2016 Kaikōura earthquake. While the time of the earthquake (12.02am) meant there were only approximately 70 observable individuals, there were several noticeable and notable behaviours. In this paper, we present and discuss apparent social influences on people's response to the shaking. In some instances, this influence was beneficial, but in many cases it was either neutral or potentially detrimental. Implications for ongoing education efforts and potential earthquake early warning messages are discussed.

Keywords Earthquake · Behaviour · Video analysis · Social norms · Social influence

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1 Introduction

1.1 Aotearoa New Zealand's earthquake context

Sitting on the boundary of the Australian and Pacific tectonic plates, with two subduction zones, a large on-land transform boundary, and vast networks of crustal faults, Aotearoa New Zealand (NZ) is prone to considerable earthquake shaking by global standards (Silva et al. 2020). GeoNet, NZ's geological hazard monitoring agency, locates approximately 20,000 earthquakes a year, with an average of over 200 of these large enough for people to feel (GeoNet, n.d.). As a result, recent research has explored how and why people are injured in earthquakes, including how their behaviour during shaking may contribute to this, in order to identify ways to reduce the injury burden.

1.1.1 Earthquake injuries

NZ experienced several significant earthquake events in the 2010s. These events started with the Canterbury Earthquake Sequence, which included the M7.1 Darfield earthquake in 2010 and the M6.3 Christchurch earthquake in 2011. The former resulted in two fatalities, while 185 people died in the latter (Abeling et al. 2020). Between 2010 and 2014, approximately 15,000 earthquake injuries were reported (Basharati et al. 2020). While not the focus of this paper, it is worthwhile to mention that nearly all earthquake related deaths are due to structural building failure (Horspool et al. 2020). These fatalities are unlikely to be prevented with protective actions during shaking, so we focus here on the behaviours which could either contribute to or mitigate the risk of injuries.

The earthquake studied here, the M7.8 Kaikōura event in 2016 (more details provided later), resulted in 618 reported injuries (Horspool et al. 2020). Consistent with previous work around the 2011 Christchurch earthquake (Johnston et al. 2014; Lambie et al. 2017), the vast majority of these injuries occurred when people fell, were struck by objects, or acted in a way which put them at greater risk than if they had done nothing. This pattern of injuries has contributed to the continuation of an annual, national earthquake drill (ShakeOut) to teach New Zealanders how to protect themselves in earthquakes (Vinnell et al. 2020). The current study aims to contribute to such public education initiatives by increasing our understanding of why people act to protect themselves - or not - and in particular, how the social environment influences those behavioural decisions (McBride et al. 2022). For example, when participants of ShakeOut were asked why they did not practise "Drop, cover, and hold" (the recommended protective actions in NZ), the most common answer was embarrassment (McBride et al. 2019), highlighting the importance of considering social influences on earthquake-related behaviour.

1.2 Video footage analysis

Much of our understanding of what people do during earthquakes comes from retrospective self-report studies, where participants provide their own account of their behaviour either in surveys (e.g., Lindell et al.; Prati et al. 2013) or interviews (e.g., Prati et al. 2012). For example, Prati et al. (2013) conducted an online survey with people who experienced the 2012 Northern Italy earthquakes. They found that people who were alone rather than with others

were more likely to stay in bed and less likely to move to another room and/or downstairs while people who were around non-family were more likely to get dressed (an inappropriate response while shaking is ongoing) than those around family. Using retrospective self-reports, Goltz and Bourque (2017) found that across three Californian earthquakes, between 6% and 19% of participants said they first went to others, typically to protect dependents.

There are significant strengths to this type of method, primarily around logistical and practical ease, and the findings have proved important for understanding behavioural responses to earthquakes. However, this type of data can be prone to biases included incorrect recollection, especially when some studies collect data years after the event (e.g., Akason et al. 2006); while "flashbulb" memories of significant events are typically held more confidently than everyday memories (Talarico and Rubin 2007) they can be less accurate (compounding usual decreases memory accuracy over time; Winograd and Neisser 2006). This means that people may not only be less likely to correctly recall their earthquake experiences, they may also be less likely to acknowledge potential memory errors. There is therefore possibly a short window after an event where memory may be fairly reliable, but it can be harmful to ask people to recount their experiences too soon after a potentially traumatic event such as an earthquake. One way around this is to examine responses to "felt reports", where members of the public voluntarily and typically without prompting provide details of their recent earthquake experience through a survey hosted by an official earthquake-related agency. For example, the United States Geological Survey collects "Did You Feel It" reports which have been analysed to explore behavioural responses to earthquake shaking (Goltz et al. 2024). Similar work is underway in NZ analysing responses to GeoNet's felt reports (Neupane et al. 2024).

Finally, self-report data is prone to response biases such as researcher expectancy (where participants give the answer which they think the researcher wants; Gephart and Antonoplos 1969) and social desirability (where participants give what they think the socially acceptable or normal answer; Fisher and Katz 1999). While these biases and limitations can be addressed to an extent, they are not entirely avoidable. Therefore, the findings from this type of data should be complemented with more "objective" data (i.e., less influenced by the participants themselves, acknowledging that biases on the part of researchers still exist). Such combinations of data types addressing related questions means that conclusions can be made with more confidence where findings align and a larger range of questions can be asked.

One approach to obtaining more objective data is to use network or agent-based modelling to predict behaviour during emergencies such as earthquakes (e.g., Gao and Liu 2017). While some of these models incorporate psychological factors, the vast number of assumptions inherent to this method means that they are not a perfect proxy for actual behaviour during events. Models also tend to focus on evacuation behaviour (e.g., D'Orazio et al. 2014). Another approach is to analyse behaviour during drills (e.g., McBride et al. 2019; Vinnell et al. 2020) or virtual reality simulations, however these situations are not an ideal proxy for actual events (Bernardini et al. 2016; Yang et al. 2011). Finally, some studies ask people what they *intend* to do during an earthquake as a proxy for actual behaviour; while intentions are one of the best predictors of behaviour, they typically account for less than a third of variance and so should not be relied upon solely (Solberg et al. 2008).

Previous studies have used video footage to analyse properties and characteristics of earthquakes such as shaking intensity and ground motion (Yang et al. 2011). Given the

increasing availability of this type of data, other studies have begun to analyse human behaviour from video footage captured during earthquake shaking. Some of this work focuses on evacuation behaviour (e.g., Bernardini et al. 2016) to refine input parameters for models. Pioneering work in NZ used CCTV footage from Christchurch Hospital during the February 2011 earthquake to understand rates of protective actions (Lambie et al. 2017) while ongoing work in the US includes analysis of social media videos from the 2018 Anchorage, 2019 Ridgecrest, and 2020 Puerto Rican earthquakes (Baldwin et al. 2021; Sumy 2023). This latter work in particular offers preliminary evidence, largely in line with existing self-report data (e.g., Goltz and Bourque 2017; Lindell et al. 2016), that adults are likely to act to protect their children and that people act differently in public and private settings. Similar research by Bernardini et al. (2019) used videos posted online to examine behaviour during earthquakes in NZ, Italy, and Japan; while the analysis focused on evacuation behaviour, the authors identified behaviour to help vulnerable individuals (e.g., elderly) and others from the same social group. However, studies of this kind are extremely limited, even though they were suggested as a way to address weaknesses in other methods decades ago (Durkin, 1985).

A study from China analysed 30 videos containing 334 individuals (Zhou et al. 2018). While this work was focused on developing a decision tree for earthquake response models, several key findings from the video analysis are relevant to the question of social influence during shaking. Over half of the individuals responded to the shaking first by looking around, with some also either communicating or continuing their task. This suggests that while the situation is uncertain, such as when people are determining if they are experiencing an earthquake, a common first response is to look for social or environmental cues; unfortunately, it is not clear what proportion of these individuals were looking around to others or looking around their environment for evidence of an ongoing earthquake. This is a key limitation of analysing CCTV footage; we can only infer motivation for behaviour based on what is visible (or in some cases audible).

1.3 Social influences

Decades of research within the domain of social psychology has demonstrated that the behaviour of those around us influences what we do in an emergency. For example, Latané and Darley's (1968) seminal "smoky room" experiments demonstrated that people are less likely to respond to smoke filling a waiting room when there are others in the room who do not react, compared to those who are alone who tend to act quickly; the implication here is that, especially in uncertain or unfamiliar situations, people look to those around them for information about the situation and behavioural cues (Goldstein et al. 2007). This research has since been backed up with hundreds of studies exploring social norms. Social norms include *descriptive* norms, which relate to how common a behaviour is, and *injunctive* norms, which relate to how acceptable a behaviour is. The former is informational (Goldstein et al. 2007); if most people are engaging in a behaviour, the assumption is that that behaviour is likely to be beneficial (there are of course instances where this is incorrect). In comparison, injunctive norms motivate behaviour by increasing social approval for conforming and/or decreasing social punishment for not conforming (Cialdini and Goldstein 2004). These two norms have been shown to be in conflict in the NZ earthquake preparedness context. Typically, people believe that preparing for earthquakes is socially-approved

but people are disinclined to act because they do not perceive that many others are (Becker et al. 2014). This disconnect might explain why high rates of knowledge of "drop, cover, and hold" are not reflected in high usage of those actions during earthquakes (Vinnell et al. 2020, 2022).

This social norm approach to earthquake behaviour is supported by other models. Based on Sime's (1985) social affiliation model, social ties are proposed as a key driver of response to emergencies such as earthquakes. This behaviour includes moving towards familiar places or people, milling, and confirming with others (Prati et al. 2012). This is similar to what is proposed in the Social Attachment Model where individuals' behaviour is expected to be based on the level of danger and the presence of social support (Mawson 2005). In contrast to the common perception that panic is a typical response, people tend to respond in emergencies like earthquakes more often in prosocial ways such as helping those around them (Prati et al. 2012) and in ways which are rational and beneficial (Goltz et al. 1992; Goltz and Bourque 2017; see for example Alexander 1990 for counter evidence).

Similarly, theories such as Emergent Norm Theory (ENT) were used to challenge the notion of panic as a typical response; instead, ENT proposes that responses to situations such as earthquakes are shaped by the social context and conform to group dynamics such as normative influence (Solberg et al. 2008). Other social psychological theories, including Social Identity Theory (SIT), have been applied to earthquake response (Drury and Cocking 2007). Under SIT, a group of people, whether familiar or strangers, will be more likely to act to help each other and, crucially, to act in coordination when faced with a shared danger such as an earthquake (Solberg et al. 2008).

Social influences on response to natural hazard events have been explored in the past; however, findings in contexts such as hurricanes (e.g., Riad et al. 1999) are limited in their application to the earthquake context given the differences in timeframe within which people are asked to act. In a hurricane context, people may have hours to days before the worst impacts to gather information and make behavioural decisions, compared to earthquakes where people are required to make immediate decisions about what to do. It is important, therefore, to test the findings and assumptions discussed above for earthquake response behaviour specifically.

1.4 2016 Kaikōura earthquake

A M7.8 earthquake occurred shortly after midnight (12.02 am) on the 14th of November, 2016. The rupture started in the Waiau Plains of North Canterbury (Bradley et al. 2017) and propagated over 150 km north (Kaiser et al. 2017), with at least 21 faults involved (Power et al. 2017). The epicentre was relatively shallow, at only approximately 14 km deep and the shaking in some areas lasted over 1.5 min. Six hundred and eighteen injuries and two fatalities were attributed to this earthquake (Horspool et al. 2020), and the impacts on business and damage to buildings cost billions of dollars (Winter 2017). While no faults in Wellington ruptured, the city experienced over a minute of noticeable shaking, including discernible P- and S-waves (see Fig. 1). It is unusual for the P- and S-waves to be so clearly discernible, with the arrival of the much stronger S-wave shaking clearly evident in the video footage (from environmental cues as well as people's reactions). The P-wave lasted about 30 s and reached a Modified Mercalli Intensity (MMI) score of 5 (moderate shaking), while the S-wave lasted over a minute and reached MMI 7 (severe shaking; Vinnell et al. 2022). This

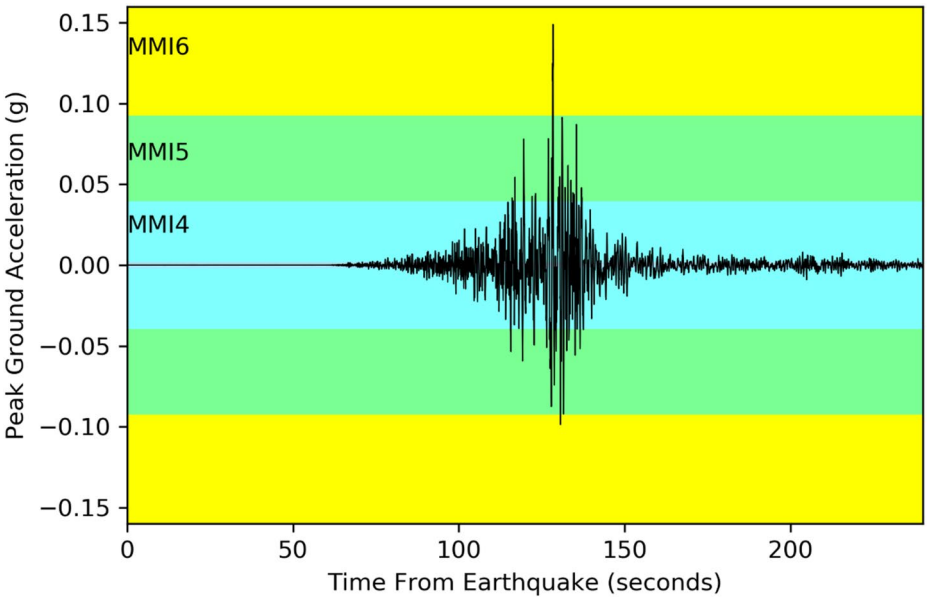

Fig. 1 Peak ground acceleration as measured in Wellington

earthquake, then, provides a valuable context for exploring human behaviour; many people in NZ, when asked why they do not protect themselves when they feel earthquake shaking, report that they wait to see if the earthquake will continue and/or get stronger (Vinnell et al. 2021). The sudden increase from moderate to severe shaking during the Kaikōura earthquake allows us to consider whether people's behaviour, and potential social influences change between light-moderate shaking where it is initially unclear that an earthquake is occurring and strong, unmistakable shaking.

2 Method

2.1 Video footage

Closed-Circuit Television (CCTV) footage during the 2016 Kaikōura earthquake was provided by Wellington International Airport. Five videos, in colour but without audio, contained a combination of members of the public and staff, including of the airport and border officials. The videos included time before, during, and after the shaking. Areas of the airport in the footage were the general terminal, baggage claim, international meet and greet area, and the Customs and Ministry for Primary Industries (MPI) arrival halls. Sixty-eight individuals were observable for enough of the video and clearly enough for their behaviour to be coded. Instances of apparent social influence are presented descriptively based on observations. These descriptions were identified by Author PI using qualitative analysis of the footage using NVivo (qualitative data analysis computer software) and checked for quality assurance by Author LV. Coding using NVivo used the same methodology as Lambie et al. (2016). Individuals were coded into the categorical data of gender, age, location,

and company (i.e., who they were with at the time). Individuals were also coded for all actions taken, including duration. Apparent triggers causing a response was coded for when possible. Seventeen individuals responded to environmental triggers (e.g., difficulty standing due to shaking). For 12 individuals, the trigger to respond was clearly social (e.g., the actions of others). Of the 68 observable individuals, 28 were identifiable as women (41.2%) and 38 as men (55.9%). Forty-three were with others (companions), four were with children (families), and 21 were alone.

Within the dataset, there were not enough instances of clear social influence to carry out formal analyses such as content analysis. Instead, this data formed the basis of the descriptions below (for more details of the content analysis of this data set, see Vinnell et al. 2022; and for details of the development of the original analysis framework, see Lambie et al. 2016). This allows for cautious interpretation of behaviour and motivations informed by specific details of the context. Descriptions of the surrounding environment is based on observation by the Authors. Unfortunately, due to privacy reasons we are unable to share the videos. Instead, we present the following as a description of what we observed in the videos as a way to prompt consideration for *potential* social influences which could be explored in future work where the source material can be shared openly.

2.2 Individual videos

2.2.1 MPI arrivals hall

In this video, some members of the public are waiting to be processed through biosecurity screening. Helpfully for our exploration, this room had two screening areas separated by an opaque wall visible in the footage. One area was in use, so there was a mix of public and staff. The other side was not in use and had only staff members.

2.2.2 Main terminal

In the main area of the terminal, before security screening, there is a range of eateries and retail stores. Given the time of the earthquake, these stores were closed. There was a limited number of both members of the public and staff present. There are two women near each other by the windows, one staff member on a raised scissor lift, and another a short distance away. Finally, a woman who appears to be on her own enters the video partway through the shaking, apparently moving towards where the others are standing.

2.2.3 International meet and greet

In this video, 19 members of the public are waiting for arriving passengers, mostly sitting with a few standing. There are two key points of interest in this video. First, approximately half of the individuals moved out of the area (and out of view), presumably to evacuate. The other half did some combination of dropping and covering (though at quite different rates). Secondly, of all the videos, this one showed the largest proportion of individuals acting in response to the lighter, P-wave shaking. This could be due to the area being on the ground floor rather than the first floor and so experiencing different shaking intensities which may be more likely to motivate action (e.g., Vinnell et al., 2021), or because the comparatively

large number of individuals meant there was a higher chance of at least one person taking action and thereby prompting others (see for example research on minority tipping points in social behaviour; Centola et al. 2018). This possibility is discussed further later.

2.2.4 Customs arrivals hall

This video also contained a large number of people (approximately 20), with most being members of the public waiting to proceed through Customs control gates. The public are queueing or entering the line, with two staff members visible positioned at the entrance and exit of the queueing area.

2.2.5 Bag belt

Finally, one of the provided videos showed the in-use baggage claim area. Luggage had not started arriving on the belt, so members of the public are arriving to the area, standing waiting, or collecting a trolley. There are no staff present when shaking starts, but approximately 15 s after shaking is visible in the footage, a staff member runs into view and appears to communicate both verbally and with gestures to the public. Two further staff appear later in the video, after the shaking has ended, to evacuate people from the area.

3 Results

Across these videos, although too limited for formal analysis, we were able to observe a large enough range of behaviours and potential influences to suggest different types and combinations of motivations. Within the video footage, there were four key types of people: Those who were on their own (individuals), with others they clearly knew (companions), with young children (families), and in the presence of uniformed staff members (authority). The behaviours exhibited differed between these different types of people.

3.1 Families

Perhaps given the time of the earthquake, there were few children present in the footage. Children are a key group to consider; it is often observed that parents act first to protect their children (Lambie et al. 2017; Vinnell et al. 2021), although previous research has found that children are more likely to protect themselves appropriately during shaking than adults (Adams et al. 2022), potentially due to regular drills in schools (for a review of adult/child dynamics, see McBride et al. 2022). In the footage of the bag belt area, an older male is standing with two children, a young girl (estimated 12–16) and a younger boy (estimated 8–12), who immediately hold on to the adult once shaking starts. As the shaking increases in strength, the three drop where they are to kneel on the ground. A few moments later, a woman runs into view (assumed to be the mother); she slows down when she sees the family cluster then drops to crouch next to them. Although a limited example, this demonstrates the importance of considering how families, and in particular parents, behave during earthquake shaking. While the motivation of the woman to reach her children is understandable,

covering distance at speed heightened her risk of a fall injury, which is one of the most common types of injuries in recent NZ earthquakes (Horspool et al. 2020).

3.2 Companions

There were several informative instances of people in the footage who were clearly with a companion. In most of the cases where there was a male and female couple, it was the woman who acted first and encouraged the man to follow. In one example the woman dropped to the floor then gestured to the man to follow, which he did. In another couple in the same video, the woman was already trying to get under furniture while the man was sitting and looking around. He then acted to help the woman get under cover before covering himself. Similarly, in the baggage claim area, a man and woman drop at the same time before the man shields the woman with his arm. In the customs arrival hall, a woman is the only person out of 68 codable individuals across the entire dataset to fully drop, cover, and hold. The man she is with clearly sees her take action but does not take action himself until the strong shaking starts. At that point he drops and shields the woman.

While the data limits the assumptions we can make about the nature of the relationships within these couples, there are two key points to note here: women are more likely to act first and men are likely to act to protect their partner rather than themselves. These points do not necessarily contradict previous findings that women have a higher injury rate in earthquakes than men (Basharati et al. 2020; McBride et al. 2022). It might be that this is the *reported* injury rate, and the difference is at least in part due to women being more likely to seek medical treatment than men in NZ (Jatrana and Crampton 2009), rather than behaviour and injury risk. Further, we identified an apparent pattern where women *without* children present were likely to act quickly to protect themselves; comparing this to the finding above where a female was seen running to her children suggests that a factor to explore in future research is whether injury rates are only lower in men compared to women when children are present. This interpretation aligns with suggestions from other scholars that differences in injury may be at least in part due to a larger proportion of women carrying out the duty of primary caregiver (McBride et al. 2022). These findings therefore show the importance of further exploring the role of societal gender norms in earthquake injuries.

In a final instance, two older women appear to be travelling together, as they can be seen standing close and talking while they wait at the bag belt. Once the shaking becomes strong, they simultaneously start moving away from the bag belt; however, one very quickly follows a staff member off screen, while the other moves a few metres towards the aforementioned family and one of the couples, to crouch next to a pillar. While they both act at the same time, they seem more influenced by the behaviour of those around them than each other; indeed, the latter women as she moves to the pillar watches her companion leave the area, but chooses to stay and drop to the ground. Interestingly, the woman who eventually followed staff out of the area had begun walking towards the pillar when the light shaking started, but then looked around and saw no one else moving so returned to stand by her companion at the bag belt. This particular example shows a potential conflict between an instinct to act in response to the environmental stimulus and a motivation to follow social cues, with the latter seeming to be more powerful. It also shows one the strengths of using video footage in that we can consider the order of people's actions.

3.3 Individuals

Across the different videos, there were several individuals who did not appear to know anyone around them. These individuals tended to pause when the shaking started before following the behaviour of others. In the baggage claim area, there were two women and two men who were standing separate from anyone else. Interestingly, and perhaps related to the above findings, both women quickly follow a staff member to evacuate the area while both men remain standing where they are. One of the men eventually crouches but otherwise does not react; the other man continues leaning against the wall for the entirety of the shaking, only moving when a staff member directs him to evacuate. While this is a limited amount of data, potential gender differences appear to be a key area to further explore. Although men are typically considered to perceive less risk from earthquakes (Spittal et al. 2005; Vinnell et al. 2018), perhaps explaining why the two male individuals did not react, this inaction is likely much safer than the behaviour of the women who evacuated, one walking and the other running. These findings support the suggestion above to further explore the potential role of gender in earthquake injuries (McBride et al. 2022). The difference in behaviour shown between individual men and women may be a result of differences in normative perceptions based on gender stereotypes, similar to those among couples, although further evidence is needed here.

Finally, in the main terminal area there are initially two pairs of people; two women who appear to be known to each other, and two members of staff. Part way through the video, a woman who appears to be on her own enters the frame and moves towards the others. Even though the woman would have been able to see the others' behaviour from a distance, she still appears motivated to be closer to other people. This suggests that behavioural modelling is not the only component of social influence, but that, consistent with the Social Attachment Model, people may act simply to be closer to others during an emergency, even if those others are strangers.

Another potential explanation for this behaviour of approaching others (such as staff) may be that the individual does not feel able to protect themselves, either by not knowing what to do or not being physically capable of undertaking protective actions. While it may be reasonable to assume anyone able to move through an airport without assistance is able to also act to protect themselves, and in New Zealand as in other countries, public education does aim to encourage modification of "Drop, cover, hold" based on physical capability, future research should explore whether the behaviour included under the Social Attachment Model may be at least in part explained by a need for tangible help.

3.4 Authority

In the Customs arrival area, there is one employee at each end of the queue of approximately 20 members of the public. Neither are observed to react until shaking is severe, when one holds a pillar. Very few individuals in this video take any action, with some crouching initially before standing again even as the shaking continues. It is unclear whether this lack of behaviour among the public was a result of seeing staff continue standing, seeing most other members of the public not taking protective action, or a combination of both. There was one individual member of the public who exhibited the correct behaviour with no apparent influence on those around her. It is likely however that an individual staff member exhibit-

ing the correct behaviour would have had more of an influence than an individual member of the public, potentially because they thought a staff member would have better knowledge of what to do (see, for example, Burger 2009; for discussion of "authority" as a proxy for situational expertise). This example demonstrates one limitation of video footage analysis, as reasons for people's action (or inaction) can only be inferred from what is visible in the footage. Previous research (Cialdini and Goldstein 2004) supports the suggestion that these members of the public were influenced by the staff behaviour; however, that research is from the US which has a higher *power distance* (a common metric for deference to authority) than NZ (Hofstede Insights, n.d.).

In the main terminal, two women were sitting together. When the shaking starts, they stand and move slowly away from the windows. At the same time, two staff members also move in the same direction. The women appear to follow the staff members after they look up towards the ceiling. When they see the staff taking no further action, the two women stop moving and hold on to each other. Another member of the public moves into view towards the employee, but also stops when she sees them not taking further actions.

In the baggage claim area, a few members of the public clearly follow the staff member who appeared, running, and communicated to them. After the shaking, other staff members appear to evacuate members of the public from the area. The woman mentioned above, who dropped by the pillar while her companion evacuated, returned to her trolley to collect her handbag before leaving. One of the staff approached her and made her place her bag on the ground, even though she had already retrieved it and was heading towards the exit. This raises the important question of what staff are trained to do; understandably they do not want members of the public delaying evacuation to retrieve items, but that was not the case here. Indeed, stopping the woman and explaining to her that she needs to leave her bag delayed both of them from evacuating.

Related to this point, there is a range of behaviour among staff in the MPI arrivals hall. In one half of the room there are four members of staff and two members of the public visible for the entire shaking. The staff direct the public to drop to the ground and hold on to their desk. In the other half of the room, not visible to the other group, are four members of staff. Two drop quickly to the ground; one sees the other two of his colleagues move quickly towards the exit and immediately gets up and follows. The other staff member does not see this and remains dropped on the ground. Even though this is the same room, and therefore the environmental cues are the same, we see markedly different behaviours both motivated by social influences. As would be expected, the public tended to follow staff instructions. It is informative that of the two staff in the other area dropped, one experiences and conforms to social influence (potentially putting himself at greater risk of injury) while the other does not. This latter individual is likely safer, although we do not know what the staff are trained to do in this instance. It is possible that protocol dictates immediately moving for a certain purpose. Future work analysing CCTV footage which contains employees should endeavour to ascertain what those employees are trained and/or recommended to do in an earthquake within their official capacity.

4 Discussion

4.1 Summary of findings

Across the videos and demographic combinations, there was clear evidence of strong social influences. The Kaikōura earthquake provides a particularly useful context given the relatively long initial period of light-moderate shaking, allowing people time to try to understand the situation before the strong shaking started. There were four key types of social influences observed: between parents and dependents, between companions, between individuals on their own and the strangers around them, and between members of the public and airport or border staff. Of note, there was considerable divergence in behaviour between companions, particularly pairs. Almost exclusively if there was a male and female pair, the woman would act first with the man typically waiting for the shaking to get stronger and then moving to protect the woman. This finding supports the established difference in risk perception between men and women (Spittal et al. 2005; Vinnell et al. 2018) and perhaps suggests a particular social dynamic which should be considered in the earthquake response context. Such questions have been explored in relation to other hazards such as hurricanes (e.g., Bateman and Edwards 2002), although the role of gender is still not fully understood (Villareal and Meyer 2019).

People on their own in particular demonstrated milling, looking to those around them for information and behavioural cues, as suggested in previous research (e.g., Prati et al. 2012). While some individuals were observed to run towards the exit, there was no observable behaviour which could be inferred as a panic response (recognising that panic does not necessarily express as physical movement), also consistent with previous research (e.g., Goltz and Bourque 2017; Prati et al. 2012). However, aside from the aforementioned couples and the staff members in the MPI arrivals hall, there was no evidence of people providing assistance to strangers or deliberate coordination. It might be that the perceived danger in this situation was too low for prosocial behaviour (i.e., aside from the ground movement itself, there were no other environmental hazards such as falling objects); it is also possible that in the context of earthquake shaking protecting oneself (or dependents) is the primary motive. These are key questions which should be explored further.

4.2 Strengths and limitations

Certain examples discussed in this paper demonstrate the strength of CCTV analysis over other methods such as self-report retrospective surveys. For example, the woman who was waiting at the bag belt with another woman exhibited a range of different behaviours with a range of environmental and social influences. By observing her behaviour throughout the entire earthquake, we can assess a more complete picture of the complexity of her behaviour by examining the different actions she took, in which order, in response to which cues, whereas a survey would likely only obtain data on which actions she took (or could remember taking; it is unlikely that an individual would correctly recall such level of detail). Using existing data such as video footage also removes the need to ask people who have experienced an earthquake, which can be unsettling and traumatic, to recount that experience for a survey or interview. Recent and ongoing work explores the strengths and weaknesses of each data type (Sumy 2023) and how they might be aligned.

The limitations of this study are inherent in the method, namely that we can only assume based on visual cues what motivated people's action. A particular limitation of the footage used here, in comparison to some other studies using videos, was the lack of audio data. There is clear evidence of verbal communication in the video, but we cannot be sure what specific information was being communicated and how. In addition, there was no internal structural damage to the building and therefore no related triggers (e.g., cues for taking actions from ceiling tiles falling) which limits the types of environmental influences which can be observed and analysed.

The consideration of audio cues raises the importance of continued research on earthquake behaviour and safety amongst deaf and hard of hearing communities. Some work has explored how to make earthquake drills and preparedness information more inclusive so that those who are deaf or hard of hearing can better respond to earthquake early warning alerts (Cooper et al. 2024). Future work exploring social influences on behaviour during earthquake shaking could explore differences between hearing and deaf/hard of hearing groups, as there could potentially be some benefit to being better equipped to communicate gesturally in loud emergency situations such as earthquakes (e.g., noise of ground shaking, noise of damage in the surrounding environment, competing verbal cues including shouting). This research focused on social cues and influence; future work could explore people's behaviour during emergencies such as earthquakes when they are in a social situation (i.e., they know there are other people around) but they cannot see or hear them. For example, it would be useful to know to what extremes people will go to gather social information when it is not immediately available. Similarly, future work could explore whether patterns of behaviour previously explained by other models such as social attachment could be, at least partially, explained by individuals with limited physical capability seeking assistance in order to take protective action (McBride et al. 2019). In the meantime, initiatives within public education to teach when and how to adapt "Drop, cover, and hold" based on context and ability should continue.

4.3 Implications

The different social influences and dynamics discussed here have multiple implications for ongoing efforts to reduce the rate of injuries due to earthquake shaking. Firstly, a clearer understanding of what people do *wrong* during earthquake shaking and why (i.e., protecting family) can inform public education efforts. Messaging around interventions such as the ShakeOut earthquake drill (Vinnell et al. 2020), run annually in NZ and in many other places around the world, convey the importance of carrying out the right actions not just for self-protection but to help guide others in the area who may not know what to do. This messaging could also directly address embarrassment, a known barrier to practising drop, cover, and hold (McBride et al. 2019) and likely a barrier to use of those actions during actual shaking.

Further, drills such as ShakeOut are often widely promoted in schools, such that children tend to have a much better understanding of, and are much more likely to implement, appropriate protective actions such as drop, cover, and hold (particularly when the earthquake occurs while they are at school; Adams et al. 2022). One potential method to reduce the rate of parents moving to protect their children, an understandable motive but one which considerably heightens their risk of injury, is to have parents practice drop, cover, and hold (or

equivalent appropriate behaviour, depending on the context) with their children. If parents know that their children can protect themselves during the immediate earthquake shaking, they may be less likely to put themselves in danger. This motivation also shows the importance of taking mitigation actions before an earthquake; while many injuries could potentially be prevented by dropping to the ground, object strike injuries can be reduced through actions such as securing furniture to walls and moving heavy objects to lower shelves. If the spaces in which a child (or an adult) spends most of their time are made safer for earthquakes in this way, then there will be less need for parents to protect their children during shaking. Accordingly, there were very low rates of injuries of children in the Christchurch earthquake because schools have resilient buildings and good practices for securing contents like furniture (Horspool 2022).

While NZ does not have an official, public earthquake early warning system into which these findings could be integrated (Tan et al. 2023; Vinnell et al. 2023), several other localities with their own systems (e.g., Japan, Mexico, and the US; Allen & Melgar, 2019) could consider what behavioural guidance is provided in alerts. For example, messages from systems such as ShakeAlert in the US tend to convey the drop, cover, and hold (on) actions. While this information is important, it may be worth researching if it would be more beneficial to include a message to *not* take actions which are commonly undertaken and raise injury risk, such as running or sheltering in doorways. The findings here suggest that as well as increasing the number of people taking correct actions having a benefit, a reduction in people taking *incorrect* actions could help protect others in the area who are not aware of what might be dangerous. For example, the footage used in this study was from an international airport, with at least some of the observed individuals having recently arrived in NZ. Although we do not know from where they arrived, it is possible that some had never been to NZ before and therefore had had no chance to learn what they should do during an earthquake. It might be that some of those who immediately ran, potentially to an exit, are from countries where this is the recommended response to ongoing earthquake shaking. As well as showing the importance of people knowing and using appropriate protective actions in case others around them are unaware of what to do, this possibility raises the question of whether new arrivals should be provided with information about local hazards and preparedness tips.

4.4 Future studies

Video footage analysis and retrospective self-reports have different strengths and weaknesses; ideally, a future study would combine the two to produce objective and nuanced data about people's behavioural motivations during earthquake shaking. Such work would require quickly obtaining video footage from a location where individuals in that footage could be contacted to participate in a survey or interview to better understand their particular thought process and clarify apparent social and environmental influences from the video. Given the unpredictable nature of earthquakes, this research may require pre-event agreements with potential footage providers to ensure data collection can move swiftly after an earthquake. It is important to note on this point however that any research which asks people to recount their experiences of a potentially traumatic situation, especially soon after that event, needs to be conducted sensitively to avoid psychological harm to participants.

Another possibility for a future study which avoids the need to wait for an earthquake is to simulate earthquake shaking using existing engineering resources such as shake tables. Such studies could use experimental paradigms including confederate experiments where one or more person within the participant group has been planted by the research team and instructed to act in a certain way. While ethical considerations would again have to be addressed and there are limitations in terms of replicating real-world situations, such methods remove the uncertainty of when an earthquake event will occur and would allow for the testing of different social influence mechanisms.

5 Conclusion

Many earthquake injuries in countries like Aotearoa New Zealand could potentially be prevented if those affected took appropriate protective actions. Social psychological research suggests that in events such as earthquakes, people may be influenced by the behaviour of those around them. Although limited, the evidence presented in this paper provides valuable preliminary evidence that social influence is a key factor in both appropriate and inappropriate actions during earthquakes. This highlights the importance of considering the role of the presence of others when seeking to understand and improve responses to earthquake shaking.

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Declarations

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