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NEW ZEALAND SOCIETY FOR EARTHQUAKE ENGINEERING

Meet EDDIE – QuakeCoRE's new earthquake test dummy

L.J. Vinnell, D.M. Johnston
Joint Centre for Disaster Research, Massey University, Wellington, New Zealand.

L. Hogan, M. Stephens
Faculty of Engineering, University of Auckland, Auckland, New Zealand.

N. Horspool
GNS Science, Lower Hutt, New Zealand.

ABSTRACT

Until recently there has been limited understanding of the relationship between behaviour during earthquake shaking and risk of injury. Studying human behaviour during shaking is important, however, because with a better understanding of the actions that put people at risk, and the contexts within which these actions occur, we can explore how to enhance safety (including via engineering solutions, or the promotion of life safety actions such as Drop, Cover and Hold). A new research direction will be the introduction of a new partner: EDDIE (Earthquake Dummy for Debris Impact Experiment). Crash test dummies or Anthromorphic Test Devices (ATD) have long been used in the automobile sector to determine the risk of injury and death from vehicle accidents. ATDs can be used to estimate the human kinematics and injury potential for different impact forces.

1 INTRODUCTION

Aotearoa New Zealand has experienced many damaging earthquakes in the past and will experience many in the future. Fifteen-thousand people were injured in earthquakes in NZ between 2010 and 2014 alone (Basharati et al., 2020), and 489 killed since 1840 (Abeling et al., 2020). Many of these injuries occur during earthquake shaking when people fall, are struck by flying objects, or undertake other actions which expose them to harm (Goltz et al., 2020; Kano, 2005; Lambie et al., 2017): as many as 91% in the 2016 Kaikōura earthquake (Horspool et al., 2020). The EDDIE (Earthquake Dummy for Debris Impact Experiment; Figure 1) project will use novel methods to reduce earthquake injuries in two ways. First, the project will provide evidence for the benefit of protective actions such as "drop, cover, and hold" as well as educational materials to educate the public on those benefits. Second, footage of EDDIE being struck by common household hazards (e.g., unrestrained furniture) will be experimentally compared to traditional public education methods for effectiveness to encourage earthquake mitigation actions. Studying human behaviour during

shaking is important, because with a better understanding of the actions that put people at risk, and the contexts within which these actions occur, we can explore how to enhance safety (including via engineering solutions, or the promotion of life safety actions such as Drop, Cover and Hold).

1.1 Meet EDDIE

A new research direction will be the introduction of a new partner: EDDIE. Crash test dummies or Anthromorphic Test Devices (ATD) have long been used in the automobile sector to determine the risk of injury and death from vehicle accidents. ATDs can be used to estimate the human kinematics and injury potential for different impact forces. In QuakeCoRE-supported research under the "Human Behaviour and Injury Project" we will be creating an ATD and using it for experiments at the University of Auckland Structural Engineering Lab to estimate the injury risk from being hit by objects in earthquakes.

EDDIE is a rough analogue for an average adult male in both height and weight. It also has moveable joints so that it can be placed in various positions. The dummy is largely anthropomorphic with some but not complete human features (e.g., the shape of eyes but no pupils, irises etc.).

Figure 1: EDDIE (Earthquake Dummy for Debris Impact Experiment). Photo credit: Catalina Miranda

2 PROTECTIVE ACTIONS

While simple protective actions such as "Drop, cover, and hold" can reduce the likelihood of injury, very few people take these steps to protect themselves (Johnston et al., 2014; Lambie et al., 2017; Vinnell et al., 2020, 2022). This is despite education initiatives such as the ShakeOut earthquake drill, developed in the United States and run nationally in NZ since 2012, appearing moderately effective at teaching appropriate protective behaviour[8]. This problem is not unique to NZ, with similar challenges in countries such as the US and Mexico to increase knowledge and, crucially, *use* of appropriate behaviour (Santos-Reyes, 2019). A recent review considered existing literature on factors related to protective actions such as social, demographic, and environmental factors as well as earthquake characteristics (McBride et al., 2022). However, little work has empirically examined the actual health benefits of recommended protective actions, in particular "Drop, cover, and hold". Given, for example, the number of people who misinterpret these actions and will cover considerable distances to reach furniture under which to shelter (Vinnell et al., 2022), empirically testing the benefits of various actions will help inform ongoing strategies to either continue with the current message, adding in more explanation about the purpose of the actions, or alter messages to the public. For example, it may be more beneficial to focus on teaching people to move as little as possible during shaking.

This phase of the project will involve placing EDDIE, equipped with impact measurement instruments on a shake table at the University of Auckland Structural Engineering Lab and simulating various potential injury scenarios. These scenarios will be informed by records of actual earthquake injuries in NZ to ensure realism and provide a more valid test. EDDIE will be fitted with force pads and accelerometers and used in experiments to estimate the injury potential of being hit by objects such as typical content items (e.g., furniture) and non-structural elements (e.g., ceiling tiles) in an earthquake. The results from these experiments will help reduce injury risk in earthquakes by identifying improvements in seismic design of non-structural elements and demonstrating the risk of injury from different protective or non-protective actions of individuals.

3 PREVENTATIVE ACTIONS

The risk of earthquakes in NZ, and particularly Wellington, is well known and yet many people are largely unprepared for such events (Johnston et al., 2013; Khan et al., 2012. Despite long-standing funding in promotional campaigns to encourage individuals to prepare (e.g., Kaye, 2016), evidence from previous research suggests that these education programmes have not led to significant increases in preparedness (Johnston et al., 2013; National Emergency Management Agency, 2021; Paton et al., 2005). Typically, people are more likely to have undertaken survival actions (e.g., storing food and water) than mitigation actions (e.g., securing tall furniture; McClure et al., 2015); given the frequency of injuries from falling and flying objects (i.e., injuries which could be avoided with appropriate mitigation actions) it is important to identify ways to increase these preparations. One key factor often found to relate to preparation is response efficacy (also termed outcome expectancy and instrumental attitudes; Becker et al., 2015; Johnston et al., 2013; Vinnell et al., 2021). This previous research has found that people are more likely to take actions to prepare for earthquakes if they know the benefits of those actions.

In line with this goal, the second phase of the EDDIE project will involve filming various object strikes, such as bookcase falling on the dummy, and then presenting this video to participants. Other participants will view traditional graphic messaging or written messaging aimed at encouraging them to take earthquake

mitigation actions. Intentions to prepare and subsequent actions will then be compared between groups. Risk perception is commonly held as a pre-requisite for preparation (Paton and Johnston, 2001) but is often not directly link with action (Bourque 2013). It is possible that traditional messaging is not "real" enough, so does not instil enough fear to motivate action. However, public education campaigns which depict people being injured (even in controlled circumstances with actors) could cause too much fear, triggering fatalistic beliefs or risk denial and inhibiting preparation action (McClure et al., 2001; Solberg et al., 2010). This phase will test whether using an anthropomorphic, but not human, object such as EDDIE will make the message tangible enough to motivate action without being too shocking for the audience.

4 REFERENCES

Abeling S, Horspool N, Johnston D, Dizhur D, Wilson N, Clement C and Ingham J (2020) "Patterns of earthquake-related mortality at a whole-country level: New Zealand, 1840-2017". *Earthquake Spectra*, **36**(1): 138-163. https://doi.org/10.1177/8755293019878190

Basharati S, Ardagh M, Deely J, Horspool N, Johnston D, Feldmann-Jensen S, Dierckx A and Than M (2020). "A research update on the demography and injury burden of victims of New Zealand earthquakes between 2010 and 2014". *Australasian Journal of Disaster and Trauma Studies*, **24**(1): 65-73. http://trauma.massey.ac.nz/issues/2020-1/AJDTS_24_1_Basharati.pdf

Becker JS, Paton D and Johnston DM (2015). "Communication of risk: A community resilience perspective". *GNS Science Report,* **2015**(66): 30 p.

Bourque L (2013). "Household preparedness and mitigation". *International Journal of Mass Emergencies and Disasters,* **31**(3): 360-372. https://doi.org/10.1177/028072701303100304

Goltz JD, Park H, Quitoriano V and Wald DJ (2020). "Human behavioral response in the 2019 Ridgecrest, California, earthquakes: Assessing immediate actions based on data from "Did You Feel It?". *Bulletin of the Seismological Society of America*, **110**(4): 1589-1602. https://doi.org/10.1785/0120200159

Horspool N, Elwood E, Johnston D, Deely J. and Ardagh M (2020). "Factors influencing casualty risk in the 14th November 2016 MW7.8 Kaikōura, New Zealand earthquake". *International Journal of Disaster Risk Reduction*, **51**: 1-8. https://doi.org/10.1016/j.ijdrr.2020.101917

Kano M (2005). "Characteristics of earthquake-related injuries treated in emergency departments following the 2001 Nisqually earthquake in Washington". *Journal of Emergency Management*, **3**(1): 33-45.

Johnston D, Becker J, McClure J, Paton D, McBride S, Wright K, Leonard G and Hughes M (2013). "*Community Understanding of, and Preparedness for, Earthquake and Tsunami Risk in Wellington, New Zealand*" Page 131-148 in *Cities at Risk: Living with Perils in the 21st Century.* Editors: Joffe H, Rossetto T and Adams J, Springer. https://doi.org/10.1007/978-94-007-6184-1_8

Johnston DM, Standring S, Ronan K, Lindell M, Wilson T, Cousins L, Aldridge E, Ardagh MW, Deely JM, Jensen S, Kirsch T and Bissell R (2014). "The 2010/2011 Canterbury earthquakes: context and cause of injury". *Natural Hazards*, **73**(2): 627-637. https://doi.org/10.1007/s11069-014-1094-7

Nikki Kaye. *$2.5m public education investment to improve Kiwi's preparedness for emergencies*. Beehive.govt.nz, 13 July 2016. https://www.beehive.govt.nz/release/25m-public-education-investment-improve-kiwis'-preparedness-emergencies

Khan S, Crozier MJ and Kennedy D (2012). "Influences of place characteristics on hazards, perception and response: A case study of the hazardscape of the Wellington Region, New Zealand". *Natural Hazards*, **62**(2): 501–529. https://doi.org/10.1007/s11069-012-0091-y

Lambie ES, Wilson TM, Brogt E, Johnston DM, Ardagh M, Deely J, Jensen S and Feldmann-Jensen S (2017). "Closed Circuit Television (CCTV) earthquake behaviour coding methodology: Analysis of Christchurch Public Hospital video data from the 22 February Christchurch earthquake event". *Natural Hazards*, **86**(3): 1175-1192. https://doi.org/10.1007/s11069-016-2735-9

McBride SK, Smith H, Morgoch M, Sumy D, Jenkins M, Peek L, Bostrom A, Baldwin D, Reddy E, de Groot R, Becker J, Johnston D and Wood M (2022). "Evidence-based guidelines for protective actions and earthquake early warning systems". *Geophysics,* **87**(1): 77-102. https://doi.org/10.1190/geo2021-0222.1

McClure J, Allen MW and Walkey F (2001). "Countering fatalism: Causal information in news reports affects judgments about earthquake damage". *Basic and Applied Social Psychology,* **23**: 109-121. https://doi.org/10.1207/S15324834BASP2302_3

McClure J, Spittal MJ, Fischer R and Charleson A (2015). "Why do people take fewer damage mitigation actions than survival actions? Other factors outweigh cost". *Natural Hazards Review,* **16**(2): 1-8. https://doi.org/10.1061/(ASCE)NH.1527-6996.0000152

National Emergency Management Agency (2021). "Disaster preparedness survey 2021". https://www.civildefence.govt.nz/assets/Uploads/public-education/report-disaster-preparedness-survey-en-jul21.pdf

Paton D and Johnston D (2001). "Disasters and communities: Vulnerabilities, resilience, and preparedness". *Disaster Prevention and Management,* **10**(4): 270-277. https://doi.org/10.1108/EUM0000000005930

Paton D, Smith L and Johnston D (2005). "When good intentions turn bad: Promoting natural hazard preparedness". *Australian Journal of Emergency Management,* **20***:* 25-30.

Santos-Reyes J (2019). "How useful are earthquake early warnings? The case of the 2017 earthquakes in Mexico City". *International Journal of Disaster Risk Reduction*, **40:** 1-11. doi: 10.1016/j.ijdrr.2019.101148

Solberg C, Rossetto T and Joffe H (2010). "The social psychology of seismic hazard adjustment: re-evaluating the international literature". *Natural Hazards and Earth System Sciences,* **10***:* 1663-1677. https://doi.org/10.5194/nhess-10-1663-2010, 2010

Vinnell LJ, Inch P, Johnston DM and Horspool N (2022). "Behavioral response to earthquake shaking: Video footage analysis of the 2016 Kaikōura earthquake in Wellington, Aotearoa New Zealand". *Earthquake Spectra,* **38**(3): 1636-1660. https://doi.org/10.1177/87552930221086303

Vinnell LJ, Milfont TL and McClure J (2021). "Why do people prepare for natural hazards? Developing and testing a Theory of Planned Behaviour". *Current Research in Ecological and Social Psychology,* **2**: 10011. https://doi.org/10.1016/j.cresp.2021.100011

Vinnell LJ, Wallis A, Becker JS and Johnston DM (2020). "Evaluating the ShakeOut drill in Aotearoa/New Zealand: Effects on knowledge, attitudes, and behaviour". *International Journal of Disaster Risk Reduction*, **48**: 1-9. https://doi.org/10.1016/j.ijdrr.2020.101721

5 ACKNOWLEDGEMENTS

The authors thank QuakeCoRE, a New Zealand Tertiary Education Commission-funded Centre, for funding and supporting the research. This is QuakeCoRE publication number 840. We also acknowledge funding from the National Science Challenges: Resilience to Nature's Challenges Kia manawaroa – Ngā Ākina o Te Ao Tūroa.