The generational gap: Children, adults, and protective actions in response to earthquakes

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Abstract

In addition to academic curricula, schools offer regular drills to train young people and adult staff on what to do in an emergency or disaster. Earthquake drills in the United States currently recommend the protective action "drop, cover, and hold on" in the event of shaking. Yet, little is known about whether this guidance is followed in schools and homes by children and adults. To fill this gap, this research examined protective actions taken by children and adults during the 2018 Anchorage, Alaska earthquake and the 2019 Ridgecrest, California earthquake sequence. Our research team conducted in-depth interviews with kindergarten to secondary school administrators, teachers, and students, as well with parents, emergency managers, building officials, and engineers (N = 118) in earthquake-affected communities. Our findings indicate that the most common action among children across the study locations was to drop, cover, and hold on. Adults, however, did not always follow current recommended guidance and exhibited more variability in the actions they took in response to shaking, such as trying to protect others, getting in doorways, freezing in place, or rapidly exiting buildings. This research suggests that a generational gap exists that could compromise the safety of young people as well as the adults who care for them. We recommend that earthquake training in schools be strengthened to better prepare both child and adult populations for the threat of earthquakes. Moreover, the emergence of new technologies, like ShakeAlert – the earthquake early warning system for the West Coast of the United States – can create new opportunities for disseminating alert and warning information and preparing populations for impending hazards. Recognising how children and adults may react in an earthquake can improve drills and messaging, refine risk communication strategies, and reduce injury and loss of life.

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In earthquake prone regions across the United States (U.S.), schools regularly provide natural hazards preparedness education and require earthquake drills for students and staff (Johnson, Johnston et al., 2014; Ronan et al., 2015). Informational materials and protective action guidance have changed over the decades as building codes have improved and research on injury and loss of life in earthquakes has advanced (McBride et al., 2022). Current guidance in the U.S. recommends that individuals "drop, cover, and hold on" (DCHO) when shaking begins (McBride et al., 2022; Rapaport & Ashkenazi, 2019). Yet little is known about whether this guidance is understood and appropriately followed in schools and homes by children and adults (Johnson, Johnston et al., 2014; Vinnell et al., 2020).

Limited available evidence suggests that individuals take a variety of protective actions when an earthquake strikes (Baldwin, 2022; Vinnell et al., 2022). These actions are influenced by a complex array of factors that include past earthquake experience, preparedness training and education, protective instincts, physical mobility, performance of the built environment, milling, and the behaviours of people in close proximity (McBride et al., 2022; Peek, 2013; Vinnell et al., 2020; Wood et al., 2018).

With this variability in mind, risk communication researchers have reached consensus that clear and consistent messaging tailored to diverse audiences and delivered by trusted messengers through multiple credible sources can help save lives (Bostrom & Löfstedt, 2003; Glik, 2007; Mileti & Fitzpatrick, 1991; Mileti & Sorensen, 1990; Steelman & McCaffrey, 2013). Furthermore, a range of theories exist to describe why people from different backgrounds do or do not take

recommended protective actions when a disaster occurs. For example, the Protective Action Decision Model (Lindell & Perry, 2012) and Emergent Norm Theory (Aguirre, Wenger, & Vigo, 1998; Drabek & McEntire, 2003; Wood et al., 2018) help to explain why protective actions may differ between people and across cultural and geographic contexts.

In this paper, we suggest that, in addition to existing frameworks, it is critical to examine how *age*—a variable that affects outcomes across the disaster cycle from preparedness to emergency response to recovery—influences certain lifesaving behaviours (Fothergill, 2017; Fothergill & Peek, 2015; Peek, 2008, 2013). Specifically, better understanding how children and adults react in an earthquake can help improve drills and messaging, refine risk communication strategies, and reduce injury and loss of life.

In this research, we examined protective actions taken by children and adults during the 2018 Anchorage, Alaska earthquake and the 2019 Ridgecrest, California earthquake sequence. Our research team conducted in-depth interviews with kindergarten to secondary school administrators, teachers, and students as well as with parents, emergency managers, building officials, and engineers (N = 118) to explore the following questions:

(a) What protective actions did children and adults take during a damaging earthquake?
(b) Was there a difference in earthquake protective actions between children and adults?

In answering these questions, this research builds on existing protective action literature by examining age-related responses to earthquakes and contributes to practical applications regarding earthquake preparedness. This study is part of a larger research project examining perceptions of earthquake early warning systems and preparedness education and training in schools on the West Coast of the U.S.

Protective Actions, Risk Communication, and Milling

As noted, several prominent theories help to explain people's decision-making when processing information about a threatening hazard. The Protective Action Decision Model describes how people process risk using environmental cues, social cues, and warnings to make decisions about how to respond to an imminent or long-term threat (Lindell & Perry, 2012). Environmental cues are what people see, hear, smell, or otherwise sense that signals a threat. Social cues are the observations of the behaviours of others related to the threat. Warnings are socially transmitted risk communication messages that are influenced by both the communication channel and the characteristics of the receiver (Mileti & Sorensen, 1990; Sutton & Kuligowski, 2019). Together, environmental cues, social cues, and warnings trigger a series of pre-decisional processes that lead to three core perceptions: threat perceptions, protective action perceptions, and stakeholder perceptions. These perceptions guide protective action decision-making and, ultimately, the behavioural response. If an individual is still uncertain about whether a threat is real or if an unacceptable level of personal risk exists, they will actively search for additional information before engaging in protective actions (Lindell & Perry, 2012).

Emergent Norm Theory explains how behaviours emerge in unfamiliar circumstances involving a potential threat (Aguirre et al., 1998; Turner & Killian, 1957). This theory posits that when there is uncertainty in a situation, people interact with each other to seek information to clarify and make sense of the situation (Locher, 2002; Turner & Killian, 1957; Wood et al., 2018). The desire for socially sanctioned meaning and direction leads to the emergence of new group norms that can influence the protective actions in which people engage (Locher, 2002). Unlike other theories of collective behaviour, Emergent Norm Theory assumes that individuals are heterogeneous actors with varying backgrounds, perceptions, and motives that shape how a situation is interpreted and what behaviours are performed (Aguirre et al., 1998).

Central to both the Protective Action Decision Model and Emergent Norm Theory is the construct of milling, the act of searching for information from others to form new shared definitions in uncertain and risky circumstances (Wood et al., 2018). Research demonstrates that when faced with ambiguous situations, people need "time to define the situation, to survey the environment, give and receive cues from others, and determine how to respond," even when there may only be seconds to analyse their environment (Goltz, Park, Quitoriano et al., 2020, p. 1,598). Within the context of emergency warnings or in response to environmental cues of an impending hazard, processing information about an imminent threat can create ambiguity, leading people to mill about to try to make sense of an otherwise uncertain situation. This process of milling, which allows people to gather additional information, can lead to better understanding of the warning, confirmation of its content, and personalisation of its risk. Together these cognitive shifts prompt people to decide whether to engage in

specific protective actions, such as to flee or shelter in place (Wood et al., 2018).

Research examining behaviours during earthquakes supports the idea that people take part in milling when faced with an unusual threat. In a study examining closed circuit television footage after the 2011 Christchurch, New Zealand earthquake, Lambie and colleagues (2017) found that nearly one-third of a sample of 213 people inside the Christchurch Public Hospital stopped to look around at others during and immediately following the earthquake shaking. These findings have also been demonstrated in video recordings of responses to earthquakes in Italy, Japan, and China where people observed the behaviours of others in their surrounding environment before taking action (Bernardini et al., 2019; Zhou et al., 2018). During the 2019 Ridgecrest earthquake sequence, Goltz and colleagues found that the majority of the 87,000+ "Did You Feel It" survey respondents indicated that they took no action when the shaking started (Goltz, Park, Quitoriano et al., 2020). The authors explain that the lack of action could suggest that people took a moment to pause, reflect, and define what was happening as the event was unfolding. They did not, however, collect follow-up interview data from respondents to verify this assertion.

Although social science literature examining how people respond during an earthquake is limited, the available evidence makes clear that human behavioural response is varied, influenced by many factors, and does not always follow recommendations for protective actions (Baldwin, 2022; Borland, 2020; Goltz, Park, Nakano et al., 2020; Vinnell et al., 2022). Studies suggest that situational conditions, such as time of day and characteristics of the built environment, demographic characteristics, and geographic location may all influence the types of behaviours that emerge—from freezing in place to running out of buildings (Drabek & McEntire, 2003; Goltz, Park, Nakano et al., 2020). Shoaf et al. (1998) found that, of the earthquake injuries they studied, those who were moving during shaking were twice as likely to be injured than those who did not move. Moreover, research has shown that reacting out of fear can cause individuals to flee or try to escape from a building rather than staying in place and seeking cover (Alexander, 1990; Prati et al., 2012). In a study examining factors that influenced injury and death during the M7.8 Kaikōura Earthquake in New Zealand, Horspool and colleagues (2020) found evidence of gendered outcomes related to protective behaviours. Women were twice as likely to be injured as men, possibly because they often move to protect others, such as children, which could increase their risk of injury (Horspool et al., 2020).

Other studies have also noted the importance of one's social and geographic location in influencing protective actions and subsequent injuries during earthquakes. For instance, research has established that children experience a higher risk of injury during shaking because of their greater physical movement, potentially unsafe schools or home environments, and reliance on the actions of adults to prompt protective actions (Alexander, 1990; Borland, 2020; Peek, 2008; Shoaf et al., 1998). At the other end of the age spectrum, older adults may also be more likely to be injured due to lower mobility and slower response times, hindering their ability to protect themselves (Horspool et al., 2020; Lindell et al., 2016; Peek, 2013).

Official Recommendations for Earthquake Protective Actions

Countries around the world have published official recommendations on how their populations should protect themselves during an earthquake. In the U.S., the Federal Emergency Management Agency and U.S. Geological Survey, among other agencies, currently advocate for DCHO as the best life-saving protective action to take during an earthquake (McBride et al., 2022). This guidance recommends that as soon as people feel a tremor, they should immediately drop to their hands and knees, take cover under a sturdy piece of furniture, cover their head and neck, and hold on until the shaking stops.

Despite these official recommendations, research suggests that members of the American public are not fully prepared for disasters, nor have they completely processed what actions are most important to take during an earthquake (Adams et al., 2017). In a representative, random sample survey of Californians, Kano and colleagues (2009) found that some of the most common misconceptions reported included believing that a doorway is the safest place during an earthquake and that the "triangle of life," which promotes curling up next to an object that will form a triangular survival void around it when it collapses, is safer than DCHO. Historical recommendations that were later debunked by the scientific community, as well as alternative guidance in areas with older and less structurally safe buildings, could be contributing to these misconceptions both in the U.S. and abroad (Rapaport & Ashkenazi, 2019). A lack of familiarity with the recommended protective actions among those who have lived outside of earthquake

hazard regions or have not received protective action training can also influence knowledge, or lack thereof, of DCHO (Sutton et al., 2020).

Holistic education about recommended protective actions is critical to keeping the public safe during earthquakes and other hazard events (Johnson, Ronan et al., 2014; Ronan et al., 2015; Towers, 2015). Schools provide a variety of educational and social services to students and community members and are particularly important for training young people and adults about how to respond during an emergency or disaster. While there are no federal laws within the U.S. requiring school districts to have emergency management plans, the majority of states and school districts require disaster planning in schools (Applied Technology Council, 2017; U.S. Government Accountability Office, 2007). This type of planning often relies largely on regularly practiced drills that vary depending on geographic location and hazard risk. These include fire, active shooter, and hazard-specific drills, such as those for hurricanes on the East Coast, tornadoes in the Midwest, and earthquakes on the West Coast. In the earthquake-prone states of California and Oregon, for instance, there are laws requiring schools to establish an earthquake emergency system that includes a school disaster plan, regular earthquake drills, and earthquake preparedness education (Earthquake Emergency Procedures, 1988; Emergency Drills and Instruction, 2011). While these mandates help promote earthquake preparedness among students, there is still significant variation in the emergency preparedness education and drills offered across the nearly 14,000 public school districts throughout the U.S. (Applied Technology Council, 2017).

Child-centred disaster risk reduction programmes that promote group learning and active participation in drills have been shown to increase knowledge, improve household preparedness, and help develop independent thinking skills that encourage children to pause and consider what might be the best action to take in a threatening situation (Johnson, Johnston et al., 2014; Johnson, Ronan et al., 2014; Rapaport & Ashkenazi, 2019; Ronan et al., 2016; Ronan & Johnston, 2003). One such programme is the Great ShakeOut, an annual campaign that encourages schools, businesses, and other organisations to practice the DCHO drill on the third Thursday of every October (Jones & Benthien, 2011). In 2020 alone, more than five million students in the U.S. participated in the Great ShakeOut drill (Southern California Earthquake Center, 2021). The programme offers drill manuals and other educational resources, such as interactive online games and earthquake simulations, to promote DCHO as the recommended action to take during an earthquake.

Even as earthquake education materials and drills reach more students and school staff in regions at risk of earthquakes, there is still a dearth of research on how children and their caregivers, teachers, and other adults respond in an earthquake. To address this gap in knowledge, this study examined and compared the protective actions that children and adults took during two damaging earthquakes in the U.S.

Methods

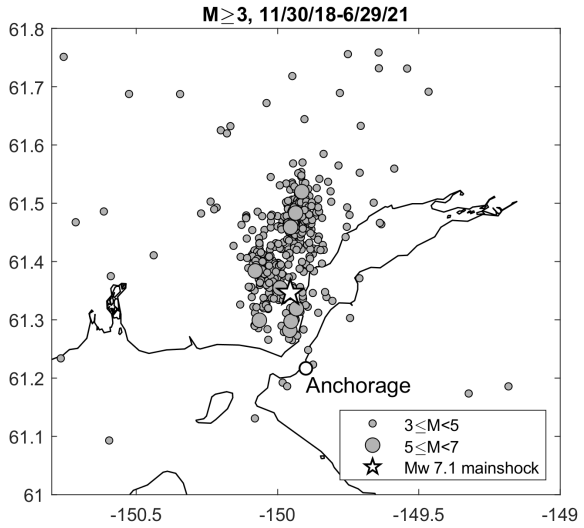
Our research team conducted a case study focusing on the experiences of children and adults following the 2018 Anchorage, Alaska earthquake and the 2019 Ridgecrest, California earthquake sequence. We chose to study these two events because the earthquakes led to widespread damage to local schools. Moreover, such events are relatively uncommon in the U.S. and are therefore important to study. The 2018 and 2019 earthquakes thus presented an opportunity to use a case study methodology, which is based on in-depth investigation and draws from multiple information sources such as observations, interviews, documents, and reports (Creswell, 2014; Yin, 2014).

Research Sites

Anchorage and the Matanuska-Susitna Borough, Alaska. On November 30, 2018, a M7.1 earthquake struck Point Mackenzie, Alaska, at 8:28 a.m. local time. The epicentre was approximately 10 miles north of Anchorage (Thompson et al., 2020). No deaths were reported due to the main earthquake, although at least 117 people were injured. Damage to roads, bridges, and other infrastructure was widespread. The earthquake activity continued for years, with more than 400 earthquakes of M3.0 and above recorded since the start of the earthquake sequence near the city of Anchorage (see Figure 1; U.S. Geological Survey, 2021).

The earthquake damaged all 92 of the Anchorage School District buildings and forced the closure of two schools due to severe damage. It impacted nearly 46,000 students and cost the district between US $25 and $50 million (Hanlan, 2018; Rodgers et al., 2021). In the neighbouring Matanuska-Susitna Borough School District, near the epicentre of the earthquake, 47 schools were damaged and an estimated 19,000 students were impacted. The district incurred more than $1.8 million

Figure 1
The Anchorage Earthquake Sequence, November 2018 to June 2021



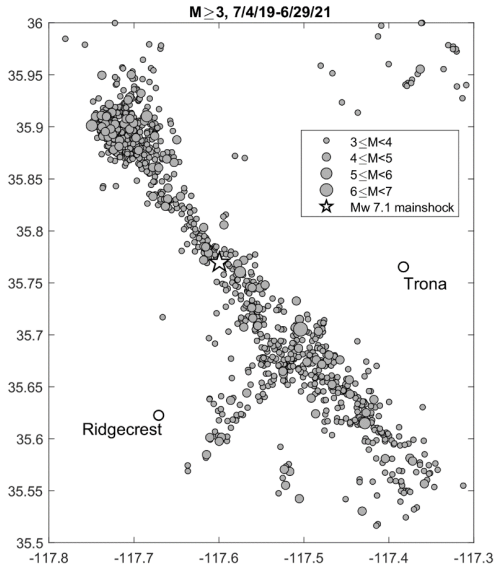
Note. In the U.S. Geological Survey Comprehensive Catalog (ComCat), there have been 449 M3-5, nine M5-7, and one M7.0+ earthquakes since the beginning of the sequence (see U.S. Geological Survey, 2021, for data on this event).

in costs, and one school was closed indefinitely (Early, 2019; Rodgers et al., 2021).

Alaska and the city of Anchorage have experienced large, damaging earthquakes in the past. The M9.2 1964 Great Alaskan earthquake, which was the second largest earthquake ever recorded on seismometers globally, destroyed infrastructure across the state (Wyss & Brune, 1967), including parts of Anchorage and surrounding areas (Kachadoorian, 1965). The earthquake, located in Prince William Sound, generated a tsunami which struck the coast of Alaska and also travelled thousands of miles to Hilo, Hawai'i, and other locations in the Pacific (Butler et al., 2017). This experience inspired more stringent building codes, which helps explain why the 2018 M7.1 earthquake caused much less structural damage than might have been expected if there had been less strenuous standards (West et al., 2020).

Ridgecrest and Trona, California. On July 4 and 5, 2019, a series of earthquakes occurred near Ridgecrest and Trona in California (see Figure 2). They included three initial main shocks of M6.4, M5.4, and M7.1, as well as many perceptible aftershocks (U.S. Geological Survey, 2019). One death was reported as were dozens of additional minor injuries. The earthquakes led to widespread infrastructure damage and power outages in the communities of Ridgecrest and Trona. Damages at the China Lake Naval Base alone were estimated to exceed US $5.3 billion (Los Angeles Times, 2019).

Figure 2
Ridgecrest/Trona Earthquae Sequence, July 4, 2019 to June 29, 2021



Note. In the U.S. Geological Survey Comprehensive Catalog (ComCat), there have been 1,002 M3-4, 99 M4-5, four M5-6, one M6-7, and one M7+ earthquakes since the beginning of the sequence (see U.S. Geological Survey, 2019, for a report on the July 4-5, 2019, events).

Schools across both the Sierra Sands Unified School District and the Trona Joint Unified School District were damaged. Of the 10 schools in the Sierra Sands Unified School District, which serves more than 5,000 students in Ridgecrest and surrounding areas, two sustained enough damage that the beginning of the school year was delayed (California Department of Education, n.d.; Neipp, 2019). The nearby Trona Joint Unified School District is comprised of one high school and one elementary school and served nearly 300 students with in-person learning opportunities before the July 4-5 earthquakes (California Department of Education, n.d.). Trona High School was forced to close indefinitely due to extensive damage to school facilities and gas and water lines. High school students were displaced to nearby Trona Elementary School after the earthquakes.

Our study area in south central California has a history of less damaging earthquake experiences than other parts of the state. However, the affected communities in the 2019 earthquake sequence are not unfamiliar with ground shaking. In fact, the area experienced another earthquake sequence in 1995, with a M5.4 being the largest recorded earthquake (Southern California Earthquake Data Center, 2022). Ridgecrest and Trona also both experienced shaking, although weak, from the 1992 Landers and 1999 Hector Mine earthquakes (Masterlark & Wang, 2002). In the two decades preceding

the 2019 Ridgecrest sequence, however, there had been little earthquake activity in the region.

Sampling, Recruitment, and Data Collection

Following approval from the Institutional Review Board (IRB) at the University of Colorado Boulder (Protocol #: 19-0803), we employed a purposive sampling technique to recruit participants for this study (for the published study protocols and research instruments, see: Adams et al., 2021; Tobin et al., 2021). Purposive sampling is the "intentional selection of informants based on their ability to elucidate a specific theme, concept, or phenomenon" (Robinson, 2014, p. 5,243). Following an in-depth search of news media coverage and reports about the events, we identified school district superintendents and other high-ranking administrators as well as other individuals who could help to inform our research, such as school principals, teachers, building officials, emergency management officials, and engineers involved in school damage assessments. We were able to identify publicly available emails for these individuals via school district websites.

We began our recruitment by first contacting school district leaders to get their approval for the study and to invite them to participate. In Alaska, we obtained a letter of support signed by the security and emergency preparedness director for the Anchorage School District and received verbal support from the safety manager at the Matanuska-Susitna Borough School District. The school districts we visited in California were smaller and did not have people employed in these equivalent roles at the district level. However, superintendents across the four school districts in our sample consented to participate in and support our research.

We then invited other school personnel to be a part of our study through personal emails sent to publicly available email addresses. We purposely sampled those with decision-making roles regarding earthquake preparedness, response, or recovery activities across the school districts. Before traveling to the study sites, we scheduled many interviews in advance, while also leaving available time to invite more participants through snowball sampling (Goodman, 1961): a convenience sampling technique where initial study participants provide names of other key informants based on their networks. We relied on snowball sampling to identify additional people who could inform our research, including parents and students who experienced the earthquakes.

Four members of our research team conducted in-depth interviews with 88 participants in Alaska from January 20 through 25, 2020, and 30 participants in California from February 17 through 20, 2020. Participants included adults and children in Alaska and California who experienced the earthquakes and/or who had extensive knowledge of the events. Of the 118 people in our sample, 35 were students. We obtained parental consent before inviting these young people to participate in the study, and these school-age children were also asked to consent before the interviews progressed.

We used IRB-approved semi-structured interview protocols to guide our conversations (Adams et al., 2021; Tobin et al., 2021). During the interviews, we asked study participants about their recent earthquake experiences, past preparedness education, protective action decision-making, and their perceptions of earthquake early warning systems. At the close of each interview, we asked participants to fill out a close-ended demographic information form (Adams et al., 2021; Tobin et al., 2021). All interview data were audio recorded after obtaining written consent from participants. During our time in the field, we also carried out observations at local community events, school board meetings, and in-school facilities for additional context. Hand-written notes and photographs were taken as well. All collected personally identifiable data were uploaded and stored on a password protected computer nightly while in the field and transferred to a secure location upon return to our university.

Data Analysis

Audio-recorded interview data were professionally transcribed and uploaded into ATLAS.ti (ATLAS.ti Scientific Software Development GmbH), which is a qualitative software analysis program. Qualitative data analysis is a multistep process that requires reading fieldnotes and transcripts, developing a preliminary codebook from themes and patterns that emerge, and coding written text to begin organising, grouping, and identifying important findings in the data (Rubin & Rubin, 2005). For this research, we created an initial codebook organised by the main themes from our interview protocols and initial codes that we knew were likely to emerge from the data after reviewing our field notes and the literature. Four of the authors then coded the interviews after testing the group coding process for intercoder reliability, which is "a measure to assess the agreement among multiple coders for how they assign codes to text segments" to reduce coder bias and increase reliability (MacPhail et al., 2016, p. 199).

Our data analysis process occurred in three stages: (1) open coding—searching for the most general themes and patterns that emerge in the data, (2) axial coding—searching for more generalisable thematic patterns, and (3) representative coding—selecting interview quotes that represent relevant findings (Marshall & Rossman, 2011). As we selected quotes for inclusion in the manuscript, we used pseudonyms and changed some minor identifying details to protect the identities of study participants.

Results and Discussion

Trends in Protective Actions

A clear generational trend emerged from our study. The most common action among school-aged children was to drop, cover, and hold on. Though there were some exceptions to DCHO, young children as well as adolescents and teens mostly followed the accepted recommended protective action, whereas adults either delayed action or followed an alternative behaviour, such as getting in a doorway or exiting the building. In general, adults frequently deviated from current guidance and exhibited more variability in the actions they took when compared to children.

Protective actions performed by children. The November 2018 Anchorage Earthquake occurred at 8:28 a.m., when students were either still at home, traveling to school in a personal vehicle or on a school bus, at a bus stop, arriving on campus, or already at school and settling into classrooms. When we asked teachers and school staff about what actions they saw the students who were already in school buildings perform during shaking, most of the respondents noted that they followed the recommended behaviours and crouched under the desks and held on until the shaking subsided. Interviews with students also confirmed these behaviours among their peers while at school.

> So it started shaking and I'm pretty sure everyone in the entire classroom was just like "duck and cover!" And everyone just ran under the tables. Everyone did it at the same time. I'm pretty sure everyone knew it was an earthquake, so everyone ducked and covered. (Student, Alaska)

To emphasise how well students performed in the Alaska earthquake, several adult and youth respondents referenced a viral video that was taken inside an Anchorage School District classroom and later placed on YouTube (https://www.youtube.com/watch?v=NJZqREPc9k0). The footage, which has been viewed millions of times, demonstrated the quick response by students to drop down under their desks and hold on, as is practiced in earthquake drills. As one respondent emphasised, the video was so powerful because it shows how drills can shape young people's reactions in an earthquake.

> I went to school here, so the earthquake drills are something that I grew up doing as well. "Get under your desk and stay there" type thing. You've probably seen the videos from ASD [Anchorage School District] that showed the students doing that. That was an amazing thing to see and has been an amazing outreach of "here's what well-trained students do." (Engineer, Alaska)

The series of large earthquakes that hit the Searles Valley in California in July 2019 took place during the summer and over a holiday weekend, when most children and staff were not in school. While a few schools were offering summer classes, the largest magnitude earthquakes occurred during the Fourth of July holiday weekend when most children were with their families. When we interviewed parents asking them how their children reacted to the trembling, a number of respondents emphasised that their children followed the recommended DCHO actions that they learned about in school. For example, a teacher and parent in California said, "My littlest one responded perfectly. Obviously, they're telling children in the elementary schools to take cover when the shaking starts. She did it without being told. So, at least at her school they told them." A school administrator related a similar situation with their child: "When the earthquake hit, little Johnny was the only one that did what he was supposed to do. The rest of us were freaking out and there he was under the dinner table."

Over the course of our interviews, we learned of a few deviations from current best practice guidance in terms of earthquake response among children. In Anchorage, for example, one of the high schools sustained structural damage when an improperly constructed wall on the second floor collapsed. We later viewed video footage that showed teens running out of the building as soon as the shaking stopped. During a subsequent interview, the principal of the school underscored that he thought the students and their teachers did the right thing in that instance, as they were unsure of the structural integrity of the building. In a middle school in the neighbouring district, an adolescent shared a story of a girl who he said "froze" and was unable to move when the shaking

started. In that case, other students helped her to get into the DCHO position.

Protective actions performed by adults. In contrast to the recommended protective actions performed by children, adult interviewees in both study sites often described widely varying reactions to shaking, including getting into a doorway, running outside, being unable to move, or doing nothing while assessing the situation and waiting for the shaking to stop. This variability among adults was in sharp contrast to the nearly uniform behaviour observed among young people, as emphasised by one of the emergency management officials in Alaska whom we interviewed:

> We saw in this earthquake that adults definitely did not know what to do. They're running out of buildings. They're standing in doorways. One place I went to said all four people stood in one doorway in their office, and I'm like, "Okay."

Even among adults who knew the recommended DCHO actions, they did not always follow the correct actions.

> We [were] sort of like "Oh my god, what's going on?" They tell you to drop underneath your desk, but what, six or seven seconds? You don't have enough time to process, "Oh it's an earthquake. Get under your desk." It's over before you even react, so we can prepare all we want. (Teacher, California)

Many adults also described practicing a combination of protective actions, such as seeking cover under a desk or table, but then once the shaking stopped, running out of the building and encouraging others to evacuate. Other respondents described how they initially froze while assessing the strength of the earthquake, but then engaged in DCHO once they had gathered adequate information about the risk level through their own personal experience or through milling and interacting with others.

> In a Magnitude 6, then you're getting under tables. But it's also how long it lasts too. I mean to be honest with you, when we had that 7.1 in November of the previous year, I was over there. I was having a video teleconference with folks. It took me about two to three seconds to kind of figure out, well, this is more than just a little tremor. And then it's like, "Oh man, should I get under the table?" And then about 15 seconds into it, it really got a little violent, and I was like, "Yeah, okay, maybe I should do something." (School District Administrator, Alaska)

Explanations for Generational Differences in Behaviour

Training. The most common explanation for children engaging in DCHO so consistently was training, with respondents attributing the behaviour to the success of school-based educational programmes and drills. Some participants described these actions as "ingrained," "almost instinctual," or "automatic," highlighting the value of developing muscle memory and procedural knowledge through regularly practicing earthquake drills. As one school administrator in Alaska said, "We used to do [drills] every month. I think honestly that probably aided in the practice piece because it's so automatic… They ducked, covered, and held on." An Alaskan student also highlighted the procedural nature of DCHO:

> Well in school the protocol is–we can't predict earthquakes. We don't know when they're going to hit, but when they do, we immediately get under our tables and hold on, cover our necks and heads, and protect ourselves as much as we can… We were starting to get to work that morning, and then the earthquake hit, and everyone just immediately got under the tables.

Similar to how children reacted based on what they learned from drills and educational programs in school, adults reverted to ingrained memory and training they had received when they were younger. When describing the protective actions they took, adult respondents were much more likely to reference outdated recommendations, such as getting in the doorway or running outside the building.

> I got in the doorway from the back room to the hallway because I was just like, "Oh yeah." It wasn't frightening. So my mind just was like, "Oh yeah, I'll go and stand where I'm supposed to be." This is how we were trained. Go stand in the doorway. That was old school. But now it's like… we need to know because things have changed and… my mind immediately went back to what you were supposed to do when I was a kid, not what you're supposed to do now that we have more information and know more. (School Staff, California)

Interestingly, many of the adults in our sample also described DCHO as "duck and cover," which was the guidance for nuclear bomb preparedness in the 1950s (McBride et al., 2022). It was not always clear whether those adults who referenced "duck and cover" used this language around children, and whether this might lead

to confusion among their charges regarding appropriate actions to take in an earthquake.

Following others. Another common explanation for how respondents reacted was following the lead of others. For instance, children in school classrooms followed the actions of their peers, which most often reinforced DCHO within the school environment. There were also descriptions of children helping each other and leading others to DCHO.

> Kids got underneath their desks. They sort of followed each other's leads on that… It was kind of fun to go back and watch the surveillance videos to see what was going on, to see people's reactions. Class was in session so there weren't a lot of kids out in the hallways, but the ones that were in the hallways basically just ran to whatever class was closest to them or the class they were returning to. So everybody acted like [snap] "Okay, this is the real deal." I think everybody acted accordingly to that. (Teacher, Alaska)

There were also several accounts of children following an adult's lead, such as listening to their teacher's instructions to drop to the floor and take cover under a desk, as one student from Anchorage noted, "We were starting to get to work on that and then it hit, and everyone just immediately got under the tables. Miss Jones yelled at everyone to get under their tables."

When children did not take appropriate recommended protective actions, they were influenced not only by their physical surroundings, but also by the adults in their homes or schools. Several adults in the study confirmed that they "grabbed" their children and attempted to flee to safety.

> But here's my thing. It's been so long since we've had an earthquake. I really didn't know what to do. I panicked, too. I grabbed my son out of bed and put him in the doorway with me. But when the other one hit, we ran out the door. (School District Employee and Parent, California)

In other instances, young children were partially or totally reliant on adults to guide them to safety. For instance, some of the parents of infants and toddlers shared with us how they reacted once the shaking began.

> And then we felt the big one starting, and it kept going and it kept getting stronger. So, we were like, "Oh, my daughter." I was like, "Come here," I grabbed her and my husband was like, "Get out!" So, we run to the door, he couldn't open the lock… So, I'm holding onto my daughter and the railing for the banister for going upstairs. My husband is trying to unlock the door and it kept locking on him, and he's getting thrown all over the place. And so, I'm like, "Take your time, calm down." … Finally, it opened and we ran outside. We see the car jumping up and down and moving down our little parking lot and everybody else coming out as well. (Parent, California)

Adults were also influenced by the actions of those around them, many of whom reinforced misguided behaviours both at work and in the home. Several respondents reported looking to others for additional information or milling before taking any action.

> So I remember I was up in the conference room up front, getting ready for a meeting and felt it. I just looked and I was like, "What's everybody else doing?" And then nobody else went under the table, we were just like, "Is it done? We're good?" Looked around, nothing fell, "Okay, we're good." (School Staff, California)

These quotes are consistent with Emergent Norm Theory, particularly as set out by Wood et al. (2018), where people will look for physical cues from those around them as to what the appropriate action is to take. These data also underscore, however, how much those actions can converge with or diverge from current recommended best practice guidance for protective actions in earthquakes, depending on the actions of peers, colleagues, friends, and family.

Responding to warning signals. At times, respondents noted confusion about how to act due to mixed messages related to warning signals. During the Anchorage earthquake, for example, the shaking triggered fire alarms in several of the school buildings, which led teachers and school staff to guide students to evacuate rather than following the DCHO actions they had practiced in earthquake drills.

> Kind of a different issue, and I don't think they've worked it out yet, is in a lot of schools the fire alarm went off, at the middle schools especially where kids think on their own a lot more. A lot of schools evacuated because of the fire alarm, but then they're evacuating through halls that have water and fallen light fixtures and things. They said they really should have stayed in place, but how do you know that? They've been discussing that with the fire department about what you do in a case like that. Is it safer to stay in the building and ignore the fire alarm assuming that it was just tripped by the earthquake, or how do you

know? Maybe there really is a fire. There's been some back and forth on that one. (Teacher, Alaska)

One school administrator in Alaska emphasised that having the fire alarm go off was a "blessing" as it allowed him to follow his instincts of wanting to evacuate the building out of fear that it would collapse.

I feel like it was sort of a blessing to have the fire alarms go off because without knowing what damage had been done to the building, whether we had a gas leak, a fire, whatever it may be, I felt like getting out of the building was the safest move, and I think a little bit of that is having that teacher that was like, "I suggest you follow me because I'm going to be the first one out the door, and I'm going to get outside."

Competing priorities. In some instances, adults ignored the recommended protective action to DCHO in response to some other competing responsibility or priority. For example, some of our adult respondents noted that the first actions they took involved helping others, such as a child or pet, or turning off utilities to protect the building.

My response was to look around for kids to see how the kids were doing. That's my primary focus, no matter what happens. My goal is to see to make sure. And there were a group of kids that had turned around, they didn't know what to do. They hadn't gotten to their class yet. So I just moved them away from glass and had them stand against the wall and stay as close to the wall as possible and told them not to move until we got some direction as to what to do. Well, it wasn't long, in fact it felt like forever, but it was after the quake had stopped shaking that the fire alarm went off. So then we evacuated the building. (School Administrator, Alaska)

Experience with local hazards. Some generational differences in protective actions could be explained by familiarity and experiences with other natural hazards or threats. Several of the adults we interviewed did not grow up in an earthquake-prone region and were therefore not properly trained on how to respond when they were in school.

There was a constant, maybe like between [Magnitude] 3s and 4s, like all the time just because of where we're at. He's just like, "Yeah, we grew up with them." I was like, "Yeah, I did not." … Like you grow up in West Palm [Beach, Florida], you know what a Category 1 hurricane is. You know that because that's what you grew up with. Well out here, they grew up with that stuff, but you don't necessarily know what that means. (Teacher, California)

Those who had moved to Alaska or California from another state were also less likely to have experienced a large earthquake before. While some had received training, such as teachers and staff who practiced the drills with students, the lack of familiarity impacted how they responded. One teacher, a native Alaskan, described how distressed her colleague was when she experienced her first major earthquake.

She was quite terrified. She grew up in Georgia. She came here from Hawaii. We have done duck, cover, holds and things before, but she was so flustered. She thought maybe a bomb had hit. She didn't know earthquakes could be that big, and she was terrified. I could hear her screaming my name as she ran down the hall, so I called her, and she managed to dive over everything on the floor and get under my desk with me. I think she wasn't prepared for how big an earthquake can be.

Emotional responses. Several respondents noted that they or people around them reacted out of fear, with the "fight or flight" response taking over. Adults shared accounts of letting fear, stress, or other emotions overwhelm them, which affected their ability to engage in the correct protective actions.

On the flip side, I found a staff member running down a hallway, and she's so frantic she literally pushes her way past kids and goes through a doorway. That's the not-pretty side of things from people that don't handle stress well. (School District Staff, Alaska)

The emotional reactions reported among children were more mixed. Some students expressed that they were not scared during the shaking, though several teachers described how frightened the children were. Despite these mixed reports, there were still descriptions of children managing their emotions and engaging in DCHO.

I will say from experience that everything from my own son, everything that was taught by his teachers, by his classroom, he did. Those kids that were there, everything they were taught, they did. If they couldn't get under, they found a wall. If they couldn't find a wall, they found a chair. They found something to protect themselves. They reacted and responded so appropriately, whether they were in kindergarten or sixth grade. Yes, they were scared, but everything they've been taught from families and teachers, they

did. They listened when they were supposed to, they went under the desk. (Teacher, Alaska)

Generational Trends Across Different Settings

Another pattern that emerged from the data regarding generational trends was that protective actions at school differ from what takes place at home. At school, children were predominantly engaging in the DCHO action that they had practiced in this setting, whereas at home, the influence of parents sometimes changed their behaviours. In addition to the instances cited above, where parents grabbed children and fled when shaking started, a school district official in Alaska shared how difficult it is for children to disagree with or change the behaviours of their parents.

> And if you watch videos, like home videos from Anchorage, every adult was running outside, which is the last thing you're supposed to do when it's shaking. Like as a community, we got lucky that no one got hurt because every single adult ran outside. All my friends ran outside. I mean, despite how much we talk about drop, cover, hold, in the Great Alaska Shakeout… They do a lot of radio stuff for that, drop, cover, hold on, and still people didn't do it. So even looking at that more so than the kids because they all knew exactly what to do. And it's sad when you see kids that are at home and they have a home video and the mom's like running down the stairs, grabbing the kid, pulling him outside. The kid's not going to [say], "No, Mom, we're supposed to get under the table." So that to me is also a big part of it. If it happened on a Saturday or a Sunday, like who knows? (School District Staff, Alaska)

Children were likely to defer to adults about what actions to take. At school, this often led to DCHO, whereas at home they were sometimes prompted to follow their parents out of the house or were told to get in a doorway. We recorded a few stories of parents telling their children not to listen to their teachers and to instead run outside of the building.

> We were at one of the schools and it was kindergarten through fifth grade out in the Mat-Su Borough… We would sit and talk with them about earthquakes and stuff. We were talking to them about drop, cover, and hold. I asked a kid, "What do you do during an earthquake?" He said to me, "At school you drop, cover, and hold on, but at home you get in the doorway." I said "What?" I talked to the kid and whatever. Throughout the summer, we heard that repeatedly across Anchorage and Mat-Su area that at home you do this. You get into the doorway. I was almost fighting with this fifth grader at one point. [Laughs] Like, "Come on, you know?" If everybody's doing this at school… But my parents tell me that. I think what I came to realise is we need to educate the parents more, but a lot of them are coming from that mindset back when that's what was taught to them when they were in school. The kids aren't going home and necessarily telling their parents. The kids are doing it, but they're not communicating to their parents the correct information, which I found very interesting. They know what the right thing to do at school is, but at home they do something different. So that was something that we realised this last year. We have a focus on youth right now, but we need to start focusing on that generation that's between 40 and 60 who still believe you're supposed to get in the doorway. (Emergency Manager, Alaska)

Discussion and Recommendations

Engaging in recommended protective actions during an earthquake is critical to reducing injury and loss of life. A growing body of research examining how people react during shaking suggests that behaviours often vary according to context and social demographic characteristics. In our study examining the protective actions taken by children and adults during the 2018 Anchorage earthquake and the 2019 Ridgecrest earthquake sequence, we identified a generational gap in behaviours performed. Our findings suggest that most children followed the recommended DCHO actions, particularly in the school setting. Adults, on the other hand, did not always follow current guidance and exhibited more variability in the actions they took.

Several explanations for the differences in behaviour by age emerged from the qualitative data. When it came to performing the recommended behaviours, school-based training and drills clearly had a strong influence among children. Earthquake-specific drills, including the Great ShakeOut, were regularly practiced in the participants' schools, allowing students to refine these behaviours as a skill. When actual ground shaking started, children reacted to the environmental cues and quickly performed the behaviours they learned in what many described as an "automatic" response. Social cues also reinforced these behaviours, with children following each other's actions and, in most cases, appropriate instructions from their teachers. Consistent with the theoretical relationships outlined in the Protective Action Decision Model, these environmental and social cues initiated a

series of pre-decisional processes and core perceptions of the environmental threat and influenced protective action decision making and, ultimately, the appropriate behavioural response (Lindell & Perry, 2012).

Conversely, the adults who participated in this study did not always follow current recommended guidance and exhibited more variability in the actions they took. Many of the adults described engaging in outdated protective behaviours that they had learned as children, such as getting in doorways. This suggests that education and drills can be effective but only when messaging is consistent over time or when recent guidance is more strongly reinforced and regularly practiced. Responding to competing warning signals and cues also influenced decision making among adults. For example, rather than following the recommended behaviours performed during earthquake drills, teachers and school staff decided to evacuate when they heard the fire alarm despite ongoing shaking. As has been documented in previous disasters, many adult respondents in our study engaged in milling by searching for additional information from others in their surroundings. Given the different behaviours performed by adults, at times this meant following others who were not performing DCHO.

Adults also experienced competing priorities and conflicting role demands as they attempted to prioritise the safety of children and pets. In the process, however, they may have placed themselves or others at risk of harm. We gathered several accounts of teachers making sure all the students were taking protective actions, while they were not able to DCHO themselves during the most active shaking. Parents who were at home with their children also described running to their children when shaking started. At times this meant grabbing their young children and running out of the house. Stories of ignoring behaviours learned in recent drills were particularly pronounced among adults who had little previous experience with earthquakes, had not grown up in earthquake country, and/or were overwhelmed or confused as to what action to take when the shaking began.

Recommendations for Improving Earthquake Education

The four school districts in this sample practiced regular earthquake drills several times per year and participated in the Great ShakeOut annually. On the one hand, it seems that these earthquake preparedness initiatives are working well for school-age children, who by and large engaged in appropriate protective actions during actual shaking. On the other hand, our research uncovered important generational gaps, with adults being much less likely to take currently recommended protective actions during the earthquakes that we investigated. We argue that these generational gaps are not the fault of the drill's design, messaging, or implementation, but rather are the result of complexities associated with generational changes in hazards education, geographic mobility, shifting responsibilities throughout the life course, and challenges with correcting long-held beliefs about protective actions among older age groups.

To remedy this issue, multiple recommendations could be considered. First, it is crucial that school-based drills actively involve students as well as adult school staff and, when possible, parents and other community members (Ronan et al., 2015). As is well recognised in disaster research, protective actions are not undertaken in isolation, but instead are inherently social (Wood et al., 2018). The process of social norming and milling means that we require cues from one another to take action when faced with alerts or physical threats. To expand on this, considerations for educating and involving the wider school and surrounding community in drills could improve outcomes for children as well as the adults who care for them. Community-wide drills, such as the Great ShakeOut or those practiced across Mexico on the anniversary of the 1985 M8.0 earthquake, can reach both adults and children in multiple settings where earthquakes take place (Santos-Reyes, 2020). These community events not only provide a meaningful opportunity for parents and children to practice DCHO together, they can also promote other interactive resources, such as earthquake simulations and video games, that may further enhance perceptions of self-efficacy to perform the recommended behaviours (Adams et al., 2017). Having parents, caregivers, and other members of the community practice DCHO can help make sure that they are prepared to protect themselves as well as the young people around them.

Second, it is important that DCHO drills are practiced in school as well as in the home and in other settings like workplaces and shopping areas. This study found that some parents were unaware of the fact that DCHO is the currently recommended best practice for earthquake protective action. Other adults actively undermined the message by telling children to take cover in doorways or to run out of buildings—actions that could lead to injury or even death in the event of falling objects. While meta-reviews of the children and disasters literature have suggested that children may be powerful risk messengers

and bring the risk information attained in school home to parents (Peek 2008; Peek et al. 2018; Ronan et al., 2016), we found little evidence of this in our interviews. This may be because written information is not sufficient to develop procedural knowledge in the caregivers of children, or because busy parents have little extra time to invest in hazard education and preparedness activities. To develop procedural knowledge, or muscle memory, education, drills, and consistent messaging (Bean et al., 2016) are required. At-home drills, modelled after the Great ShakeOut, with school children and their parents may be one way to address this issue. Another way could be to include drills at parent-teacher association meetings, school board meetings, or parent-teacher conferences.

Third, targeted and enhanced education for teachers, school staff, and other adults is vital. As our research revealed, adults who received earthquake education may have been taught to take protective measures—such as sheltering in a doorway or running outside—that are no longer recommended. When the recent earthquakes occurred, they reverted to what they were taught in their youth, and therefore did not always model appropriate behaviours for their students or children. Teachers and other adults who grew up outside of earthquake country had limited knowledge of protective actions or were unprepared for how frightened or stressed they would be in the event of an actual earthquake. Teachers, school staff, parents, and other caregivers hold powerful responsibilities for young people's health and well-being, and it is therefore imperative that they also see themselves as the focus of earthquake education materials and drills.

Fourth, in the regions of the U.S. that are most at risk to earthquakes, earthquake education should be integrated in classes beyond the earth sciences. Although K-12 school curricula vary widely in the U.S., Next Generation Science Standards (2017) require that students learn about earthquakes during the fourth grade and as part of their core science curriculum. We suggest that integrating earthquake case studies throughout curricula and across grade levels could help engage educators more deeply in earthquake preparedness and could help socialise more students and teachers in proper protective actions.

Fifth, future earthquake education programmes and drills could be more connected to recent scientific advancements surrounding earthquake early warning (Becker et al., 2020; McBride et al., 2022). Indeed, with the recent introduction in California, Oregon, and Washington of ShakeAlert, the earthquake early warning system for the West Coast of the U.S., some schools can potentially receive seconds of notice that earthquake shaking is imminent (McGuire et al., 2021). ShakeAlert warning messaging was crafted to focus on what is happening (earthquake) and protective actions (DCHO and protect yourself now), along with post-alert messaging (McBride et al., 2020). This technology may provide an opportunity for further dissemination of the DCHO message to more people in earthquake-prone regions of the U.S.

Limitations

As with all studies, this one has limitations that should be acknowledged. Our sample was non-representative and therefore we cannot speak to precisely how many children or adults engaged in appropriate or inappropriate protective actions in either case study setting, or just how wide was the generational gap we observed. While we sought out people from different demographic and organisational backgrounds, we also cannot detail specific patterns by race, gender, or geographic region of origin, for instance. Because major earthquakes are relatively rare in the U.S., our case study communities in Alaska and California were not necessarily representative of the states as a whole or the larger regions where they are located.

Conclusions

With these limitations in mind, this research has uncovered a potentially important pattern that warrants further investigation. In particular, it is important that researchers collect age and other demographically disaggregated data. It is also vital to include children as well as adults in study samples. To date, the vast majority of earthquake-focused research—as with other disaster research—has focused on adults and then has used adult voices to describe "people's" experiences (Peek, 2008). But children under the age of 18 make up close to one-quarter of the population in the U.S. and an even higher percentage in other nations around the world (Peek et al., 2018). As this research revealed, their actions and experiences may vary widely from the adults that surround them. It is vital to acknowledge this variability, and to ensure that our education programmes, drills, and warnings are implemented with an awareness of and sensitivity to this variability. The safety of current and future generations is at stake, and it is important that we see these differences and harness them to promote public safety and the broader collective good.

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Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government. ShakeAlert is a registered trademark of the U.S. Geological Survey managed ShakeAlert Earthquake Early Warning System operating in the United States of America and is used with permission. Figures 1 and 2 were generated using seismicity data from the U.S. Geological Survey Comprehensive Catalog (ComCat), last accessed on June 28, 2021.

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