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How Many Injuries can be Avoided through Earthquake Early Warning and Drop, Cover, and Hold On?

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Abstract

One of many potential benefits of earthquake early warning (EEW) is the reduction in injuries because people have more time to drop, cover, and hold on (DCHO). I offer an initial estimate of the potential benefit of EEW and DCHO in a hypothetical Mw 7.0 earthquake on the Hayward Fault in the San Francisco Bay Area, both in terms of avoided injuries and the acceptable cost to avoid those injuries from the perspective of the US government. I estimate that out of 18,000 estimated nonfatal injuries in the scenario earthquake, up to 1,600 people who would otherwise be injured could complete the DCHO actions before the arrival of strong motion. Of these 1,600 people, I estimate that DCHO would prevent up to 89 percent of injuries. As a result, the combination of EEW and DCHO could prevent up to 1,400 injuries, 8 percent of the total. The value of these injuries is approximately $300 million. This is not the same as the probabilistic benefit of EEW and DCHO because it is conditioned on the occurrence of a single earthquake among many whose occurrence is uncertain. It is however a useful index of the potential benefit of EEW. The figures—1,400 avoided injuries and $300 million value of statistical injuries avoided—may represent upper bounds because I do not know how effectively DCHO prevents injuries. The estimate does not include injuries that are avoided by people performing DCHO after the arrival of strong motion presumably this number is a substantial fraction of the 18,000. If DCHO is highly effective even without EEW, the benefits of combining EEW with DCHO might be less.

Introduction

Background

Earthquake early warning (EEW) can provide several seconds' advanced warning before the arrival of strong motion. In that time, a person who receives the warning can take self-protective action. As of this writing, the American Red Cross, Earthquake County Alliance, and others recommend a sequence of actions to protect oneself entitled drop, cover, and hold on (DCHO). To DCHO, a person drops to hands and knees on the floor, covers head and neck with the arms, and if there is sturdy furniture such as a table nearby under which to take shelter, crawls there and holds on to the table legs to ensure that the cover does not slide away from the person. DCHO is also used as a shorthand to cover a variety of additional advice for what to do during earthquake shaking in a variety of situations, such as outdoors, in a vehicle, and in a stadium etc. The Earthquake Country Alliance advises people to DCHO to reduce the risk of injury, especially from falling objects (see, e.g., http://earthquakecountry.org/step5/).

However, assuming DCHO is highly effective at reducing the risk of injury, then using EEW to get to cover sooner, before earthquake shaking arrives and causes items to fall, should further reduce injuries in earthquakes. To my knowledge no one has quantified the efficacy of DCHO: we do not know by how much DCHO reduces earthquake injury risk, nor do we know the benefit of partially completing DCHO before strong shaking arrives. One can estimate its efficacy by assuming that completing DCHO prevents all earthquake injuries associated with falling, contents, nonstructural components, and actions such as jumping out of windows or attempting to catch falling objects. Let us further assume that partially completing DCHO prevents some of these injuries.

Objectives

Let us estimate the benefit of earthquake early warning in terms of the number of human injuries that could be avoided if a large earthquake were to occur after the population of the San Francisco Bay Area were all trained and drilled on DCHO and equipped with EEW. Let us also estimate the economic value of the avoided injuries. I do not examine other applications of EEW such as stopping trains, opening fire station doors, moving elevators to the nearest floor before power goes out, etc.

Literature review

Earthquake early warning has been in development since at least 1995, with the goal among others being to reduce deaths and injuries. See, e.g., Anderson et al. (1995), Lee et al. (1996) or Gasparini et al. (2007). EEW has been implemented in Japan and is available as a free app for smart devices such as Yurekuru Call for Android (e.g., Sung 2011). In the United States, the United States Geological Survey (USGS) along with a coalition of university partners are developing and testing an earthquake early warning system called ShakeAlert for the west coast of the United States (Burkett et al. 2014).

If EEW can avoid injuries, it is possible to assign an economic value to the avoided injuries. Since 1993, the US government has been required to demonstrate the cost effectiveness of new regulations, including those intended to enhance public safety (Clinton 1993). To do so it has had to establish an acceptable cost to avoid statistical deaths and nonfatal injuries. By "statistical deaths and injuries" is meant deaths and injuries to unknown persons at some uncertain future date, as opposed to the value of a particular person's life or present or past injury.

Different agencies of the US government assign these values differently, but produce generally similar values. The US Department of Transportation (USDOT 2014) recently assigned a value of $9.1 million per statistical fatality avoided in 2013 US dollars, lesser values for nonfatal injuries, and an inflation factor of 1.18 percent per year to use for years after 2013. The degree of the nonfatal injuries is measured using the Abbreviated Injury Scale (AIS) of the Association for the Advancement of Automotive Medicine (2001).

In MMC (2005), colleagues and I employed Hazus-MH's estimates of deaths and injuries to estimate the cost effectiveness of natural-hazard mitigation, producing the oft-quoted value of $4 saved for every $1 invested by FEMA on natural-hazard mitigation. To do so, I related Hazus-MH 4-level injury severity scale to the 6-level scale of the AIS, using the definitions both authorities provide.

The potential benefits of avoiding earthquake injuries are great. Porter et al. (2006) show that the injuries experienced in the 1994 Northridge earthquake had an economic value of \$2 to \$3 billion in 2005 USD. That is, if all of the injuries in the 1994 Northridge earthquake could have been prevented, the US government would have deemed an expense of up to \$2 to \$3 billion to do so justifiable. That work drew on Shoaf et al. (1998), who offer statistics on the number, severity, and causes of injuries in several earthquakes, including the 1994 Northridge earthquake. They show that 55 percent of injuries in that earthquake were caused by nonstructural damage, 22% by the "physical force of the earthquake," 12 percent by behavior such as jumping out a window, 1 percent by "structural objects," and the 10 percent by other causes. These statistics can provide insight into the fraction of injuries that might realistically be prevented or avoided by DCHO. Johnston et al. (2014) provide analogous statistics for the 2010 Darfield and 2011 Christchurch, New Zealand earthquakes.

Methodology

Estimating avoided injuries

I wish to estimate how many fewer people would be nonfatally injured in a large earthquake if everyone in the affected area received EEW and had been well trained and drilled on drop, cover, and hold on. Let us refer to the reduction as the injury-prevention benefit from the combination of EEW and drop, cover, and hold on, or EEW+DCHO. Let us denote the benefit by *B*. Let us associate earthquake deaths entirely with structural collapse and assume that DCHO would prevent few if any of them, so the EEW+DCHO benefit would only be considered to accrue only from the reduction in nonfatal injuries and causes other than structural collapse. Let us estimate *B* in any particular location *i* as the product of three quantities:

I = number of nonfatal injuries under as-is conditions (without EEW),

$F(t)$ = fraction of occupants who could in principle DCHO after receiving EEW and before arrival of strong motion t seconds later, and

f = fraction of nonfatal injuries that could be avoided by DCHO.

Then the upper bound of avoided injuries in a particular earthquake can be estimated as:

$$B = \sum_{i=1}^{N} I_i \cdot F(t_i) \cdot f \qquad (1)$$

where I_i denotes the number of nonfatal injuries estimated in geographic location i (e.g., a census tract or ZIP Code), $F(t_i)$ denotes the fraction of people in location i who could take effective self-protective action within the available warning time t_i, f is the fraction of injuries that could conceivably be avoided through DCHO. Note that Equation (1) assumes that if one is halfway through DCHO, the benefit is half as much as if one has completed DCHO, and a similar proportion for other degrees. The multiplicands can be estimated as follows:

I_i is estimated using Hazus-MH.

t_i is the warning time at location *i*, the time between receipt of the EEW message and arrival of S waves:

$$t_i = \frac{R_i}{V} - t_L \qquad (2)$$

R is hypocentral distance to location *i*, km

V is the shear-wave velocity in rock

t_L is latency time, from earthquake nucleation to transmission of the warning

$F(t_i)$ can be estimated as the cumulative distribution function of DCHO reaction time from a population survey evaluated at t_i, the warning time for location *i*.

f can be estimated using data compiled from injuries suffered in the Northridge and possibly other earthquakes. Shoaf et al. (1998) provide the necessary data: 55% of injuries result from nonstructural objects, 22% from earthquake force, and 12% from behavior. It seems reasonable that effective DCHO could prevent injuries from nonstructural objects by shielding the person from falling or sliding nonstructural objects. It also seems reasonable that DCHO could prevent injuries associated with earthquake force, by having the person drop to the floor on hands and knees and therefore avoid being thrown by the force of the earthquake. Finally, DCHO is a behavior that substitutes for injurious ones such as jumping out of windows or trying to catch falling objects—two examples of behavior-related injuries in Northridge. Summing these injuries, it seems as if DCHO could conceivably prevent 0.55 + 0.22 + 0.12 = 89 percent of injuries, suggesting *f* = 0.89. The remaining 11 percent of injuries were associated with structural objects (1 percent) and other causes (10 percent). Although some furnishings have supported structural objects in past earthquakes, it seems conservative to assume that this is not a general case, so let us omit the 1 percent of injuries associated with structural objects from potential benefits of DCHO. Shoaf et al. (1998) provide no additional detail regarding the remaining 10 percent of injuries associated with other causes; let us assume that DCHO would not prevent these either. I am aware of no research on the effectiveness of DCHO, so *f* = 0.89 should be thought of as an upper bound on the number of nonfatal injuries that would in practice be avoided by DCHO.

Note that Johnston et al. (2014) categorize causes of injuries differently from Shoaf et al. (1998) and lump together injuries that occurred during the earthquake and in its aftermath, such as helping others or injuries caused by glass. As a result, it is problematic to estimate *f* using Johnston et al.'s (2014) data. Depending on what one includes and excludes, one can estimate *f* from these data between 69 percent and 99 percent. At least the range overlaps and therefore does not contradict the value derived using Shoaf et al. (1998).

The value of $F(t_i)$ can be taken as the cumulative distribution function of DCHO reaction time.

Estimating the acceptable cost to avoid injuries

One can calculate the acceptable cost to avoid statistical injuries B_2 as suggested in MMC (2005) as follows:

$$B_2 = \sum_{j=1}^{3} B_j \cdot V_j \tag{3}$$

where B_j denotes the number of avoided injuries of severity j and V_j denotes the Federal government's acceptable cost to avoid a statistical injury of severity j. Let us take values of statistical injuries avoided from USDOT (2014), inflate them to 2015 USD as instructed there, and map them to Hazus-MH injury severity levels using MMC (2005) Table F-5 mapping 2. Table 1 presents those figures, rounded to two significant figures to avoid the appearance of excessive precision.

Table 1. Acceptable cost to avoid a statistical injury

Hazus injury severity	Acceptable cost per avoided injury ($)
1. Basic medical aid by paraprofessionals	$28,000
2. More than 1 but not life threatening	$660,000
3. More than 2 but not immediately fatal	$3,700,000
4. Fatal	$9,400,000
Total	

Survey design

I developed a data-collection protocol to collect statistics about DCHO reaction time via a web-based survey instrument copied to Appendix A. The protocol was approved by the University of Colorado Boulder's Institutional Review Board on 17 Nov 2015. The survey instrument has six parts:

1. An introduction that explains the purpose of the survey, its procedures, risks, benefits, confidentiality, and consent to participate
2. Training materials—text and brief YouTube videos—on how to DCHO
3. Instructions on where and how to time oneself performing DCHO
4. A question to determine the setting where the volunteer performed the exercise, in terms of Hazus-MH occupancy classification
5. A series of questions to examine how well the training material worked
6. Demographic questions

In an initial study, volunteers were recruited via the Twitter feed of Dr Lucile Jones, the web page and Twitter feed of ShakeOut.org, and my own social media contacts through LinkedIn, Twitter, direct email, and personal appeal. Almost all responses were from my direct requests, some from an email appeal by Charles Scawthorn, and virtually none responding from the other sources. The initial study yielded only 65 responses, so the earlier sample was ignored and more than 500 participants were recruited via Qualtrics Panels, a paid service provided to the University of Colorado Boulder. Subsequent findings refer only to responses from Qualtrics Panels.

Findings

Distribution of DCHO reaction time

Data were collected using the survey instrument in Appendix A between 18 and 23 December 2015. As of this writing, I collected data from a large sample: *n* = 525 people completed the survey out of 638 to whom the survey was sent, a response rate of 82 percent. Let us refer to these data as round-1 surveyed reaction times, in case future surveys are performed. Many of the data appear to reflect an incorrect understanding of when to stop counting or data-entry typographic errors: 38 respondents reported times in excess of 20 sec, some as long as 200 sec. Omitting these 38 responses, the remaining 487 responses are shown in Figure 1 along with a lognormal distribution fit to the data.

The nontechnical reader can interpret Figure 1 as follows. The dashed, stairstep line represents the survey respondents' reaction time. For example, 10 percent of them were able to DCHO in 5 seconds or less (see how the dashed line passes through x = 5 sec, y = 0.10), 50 percent in 9 seconds or less (x = 9 sec, y = 0.50), and 90 percent in 15 seconds or less (x = 15 sec, y = 0.90). The smooth S-shaped curve is a parametric distribution called the lognormal cumulative distribution function. It approximates the stairstep line with a more convenient mathematical equation. It is closely related to the familiar bell-shaped curve called the normal or Gaussian distribution. The lognormal cumulative distribution function has two variables that determine its shape. One of the variables, called the median, adjusts the *x*-value associated with the midpoint of the curve (i.e., the *x*-value associated with y = 0.50). The other variable, called the standard deviation of the natural logarithm of the variable (or logarithmic standard deviation), adjusts the width of the S-shaped curve.

The reader should understand that lognormal may be the parametric probability distribution more commonly used than any other in earthquake engineering. Engineers use it for any of several reasons: (1) it often reasonably agrees with observations of real-world variables, as it does here; (2) like many real-world variables, it can only take on a positive value and has a specifiable median and logarithmic standard deviation; (3) it assumes the least knowledge about the variable in question, conditioned on the value of the median and logarithmic standard deviation; and (4) tradition—engineers have used the lognormal at least since the 1980s to characterize earthquake damage to building components.

With the survey one can estimate that reaction time is approximately lognormally distributed with median 8.8 sec and standard deviation of the natural logarithm equal to 0.40, as shown in Figure 1. The lognormal appears to be a reasonable approximation of the sample data provided by the study participants.

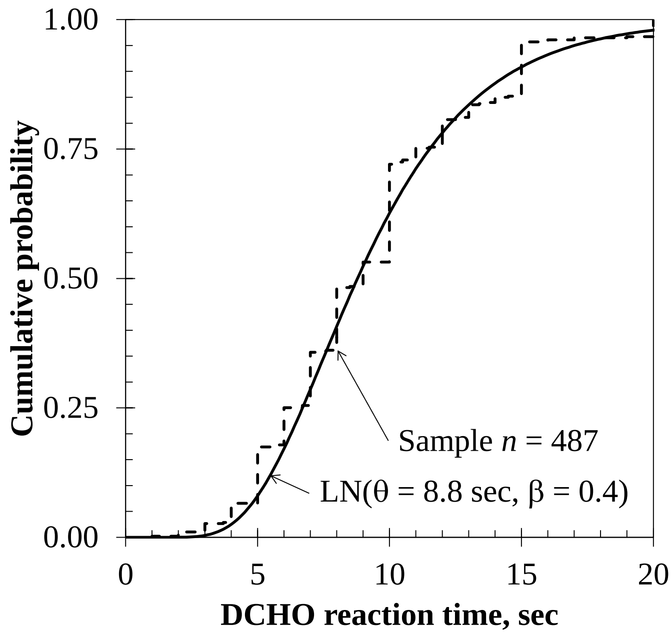


Figure 1. DCHO reaction times

Respondents were aged between 18 and 95, with a mean age of 35. The majority of respondents (57 percent) were female, versus 50.8 percent in the general U.S. population in 2014 (according to http://quickfacts.census.gov/qfd/states/00000.html). Most (69 percent) described their race or ethnicity as white/Caucasian (versus 80 percent among the U.S. population in 2014, according to Colby and Ortman 2015), 13 percent African American (versus 14 percent for the U.S. population), 10 percent Hispanic (17 percent among the U.S. population), 8 percent Asian (versus 6 percent in the U.S. population), 3 percent Native American (2 percent among the U.S. population), 1 percent Pacific Islander (same as the U.S. population), and 4 percent other (respondents were allowed to select all that applied). The majority (56 percent) have at most some college (U.S. population: 61 percent, according to U.S. Census Bureau 2015a), 33 percent have a 2- or 4-year college degree (U.S. population: 28 percent), and 11% had a masters, professional, or doctoral degree (U.S. population: 10 percent). Respondents were slightly poorer than the U.S. population in general: 53 percent report a combined household income less than $40,000 per year (U.S. median household income: $53,657, according to U.S. Census Bureau 2015b), 91 percent report less than $110,000 per year (90th percentile among the U.S. population: $155,000).

Calculation of benefits

Let us now apply the foregoing procedures to evaluate the benefits of the combination of EEW and DCHO in a large hypothetical earthquake in the San Francisco Bay Area. In particular, let us assume the occurrence of an Mw 7.0 earthquake rupturing the north and south segments of the Hayward Fault, with an epicenter below Oakland, California. See Aagaard et al. (2010a, b) for details of the earthquake. See Figure 2 for a map of the estimated shaking in terms of 5%-damped elastic spectral acceleration response at 0.3-second period.

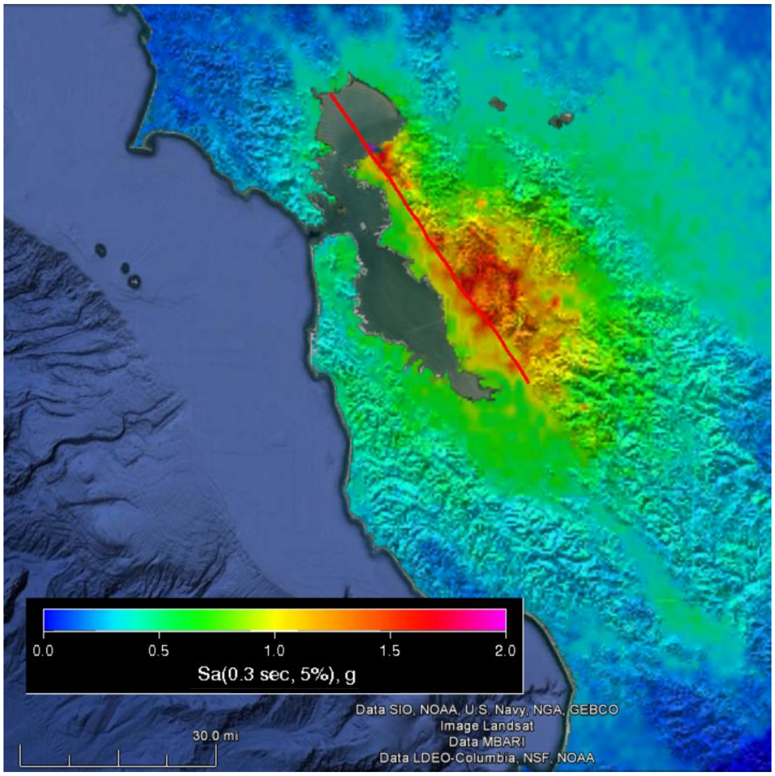


Figure 2. Scenario shaking in terms of 5% damped elastic spectral acceleration response at 0.3-second period

Warning time t_i of Equation (2) is shown for the mainshock in Figure 3. One can now apply Equations (1) and (3). With invaluable help from Jamie Jones of the USGS, I compiled I_i by census tract from unpublished Hazus-MH analysis of the earthquake provided by D. Bausch (written commun., 20 Jun 2014). Jones also calculated R_i at each census tract centroid, taking V = 3.4 km/sec and t_L as 5 sec. One can idealize $F(t)$ as lognormally distributed with median reaction time equal to 8.8 sec and logarithmic standard deviation equal to 0.40, i.e.,

$$F\left(t\right)=\Phi\left(\frac{\ln\left(t/8.8\,\mathrm{sec}\right)}{0.40}\right) \tag{4}$$

The total number of nonfatal injuries in the scenario earthquake is estimated to be 18,100; EEW could avoid up to 1,500 of these, or 8 percent. Note that this estimate does not include injuries that are avoided by people performing DCHO after the arrival of strong motion. If DCHO is highly effective even without EEW, the benefits of EEW+DCHO might be less.

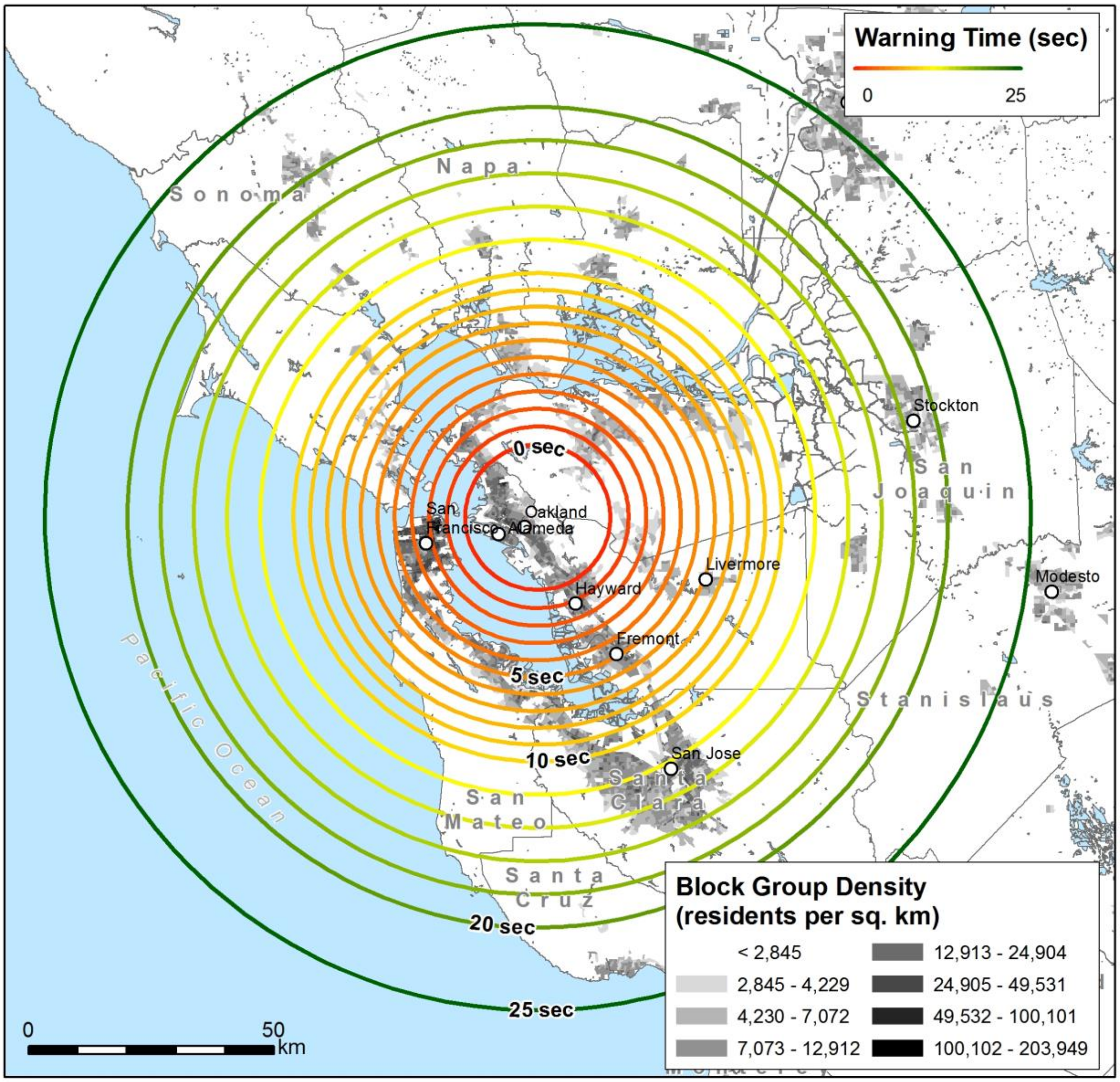


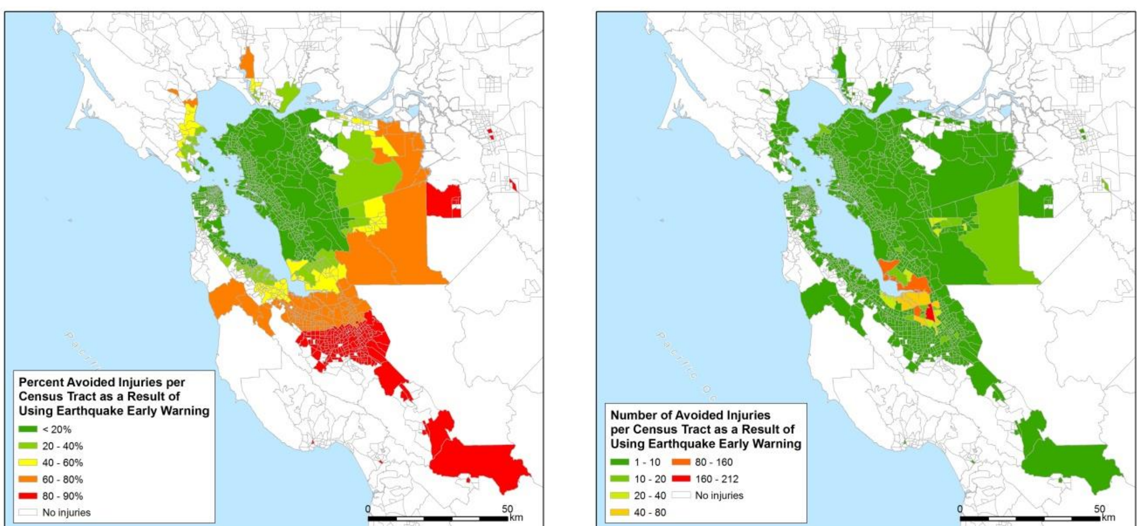
Figure 3. Contours of warning time t_i for a Mw 7.0 Hayward Fault earthquake centered below Oakland, California

The results are shown in Table 2. Dollar values in the table are rounded to two significant figures. The table suggests that if EEW were fully implemented and everyone in the Bay Area had been trained and drilled on DCHO before the earthquake occurred, up to 1,600 people who would otherwise be injured would have time to complete DCHO before the arrival of strong motion, and up to 1,500 nonfatal injuries could be avoided. The acceptable cost to avoid those injuries is $300 million. Recall that the results in Table 2 assume that completing DCHO effectively avoids 89 percent of injuries, which was acknowledged as an upper bound. The actual benefit would be lower in proportion to the ratio of actual nonfatal injuries avoided to the upper bound. Note also that some of the injuries shown in the first column would also be avoided by DCHO without EEW, since the Hazus injury model predates widespread training in DCHO. Perhaps DCHO would be less effective in the absence of EEW because people would be trying to take action during strong motion, and would be injured before successfully completing the DCHO actions. I do not speculate on injuries avoided by DCHO without EEW.

Table 2. Upper-bound number and value of avoided injuries from EEW+DCHO in the scenario earthquake

Hazus injury severity	Injuries (people)	Max avoided injuries	Acceptable cost per avoided injury ($)	Acceptable cost to avoid ($ million)
1. Basic medical aid by paraprofessionals	14,081	1,216	$28,000	$34
2. More than 1 but not life threatening	3,491	218	$660,000	$144
3. More than 2 but not immediately fatal	558	34	$3,700,000	$127
4. Fatal	971	0	$9,400,000	0
Total	19,101	1,468		$ 305

EEW is provide more advanced warning the farther the recipient is from the earthquake focus (Figure 4A), but injuries tend to concentrated close to the focus. It is in the middle ground, where EEW provides at least some warning time but shaking is still strong enough to threaten life safety, that EEW has the greatest potential to reduce injuries, as shown in Figure 4B.



A B

Figure 4. A. Fraction of injuries potentially avoided by EEW. B. Upper bound number of injuries avoided by census tract

Conclusions

I do not know how effective DCHO is in preventing earthquake injuries, nor do I know how much time decision-making adds to DCHO reaction time. However, to begin to estimate the benefit of EEW and DCHO, I assume that training and drilling can reduce decision time to near zero relative to reaction time.

I further neglect the benefit of DCHO without EEW, and assume that DCHO before the arrival of strong motion can prevent almost all (f = 89 percent) of nonfatal earthquake injuries. With all of these simplifying assumptions one can estimate an upper bound to the benefit of the combination of EEW and DCHO. If everyone in the San Francisco Bay Area were trained and drilled in DCHO and equipped with EEW before the occurrence of the earthquake, the additional warning time provided by EEW would be sufficient for 1,600 of 19,000 people who would otherwise be injured or killed to take DCHO actions before the arrival of strong motion. If DCHO were completely effective in avoiding the 89 percent of nonfatal injuries associated with nonstructural objects (55 percent), earthquake force (22 percent), and behavior (12 percent), then 1,500 nonfatal injuries could be avoided among the 1,600 who would otherwise be injured or killed. The US government would value mitigation measures to avoid that number of nonfatal injuries at approximately $300 million (2015 USD). (Again, I lack experimental evidence to support the 89 percent figure, so 1,500 injuries and $300 million may represent something like upper bounds. I ignore the possibility that DCHO could prevent fatalities because there appears to be no prior research to suggest a reasonable fraction of fatalities that could be avoided.)

Limitations and research needs

All this is not to say the probabilistic benefit of EEW and DCHO is $300 million, for several reasons. the figure is an upper bound, not an expected value. And it is conditioned the occurrence of a single earthquake, when in fact the future date of such an earthquake is uncertain, and there are many other possible earthquakes where EEW and DCHO would contribute to probabilistic benefit. The figures of 1,500 injuries and $300 million are, however, useful to understand the potential magnitude of the benefits of EEW and DCHO.

There does not appear to be any published research or other evidence on the effectiveness of DCHO to prevent injuries. It is unknown, for example, how many injuries related nonstructural objects would actually be avoided by DCHO. Or injuries associated with earthquake force or behavior. I assumed nearly all, and assumed that none of the remaining 11 percent of deaths and injuries could be avoided by DCHO.

Other important, unanswered questions include the following: How much would reaction times differ in the real event as opposed to the calm setting of the survey? What fraction of injuries can be avoided without EEW, that is, if people DCHO when they begin to feel strong motion? How long after the initiation of strong motion do injuries occur? Presumably the answer to that question depends on the severity of motion during the first 5 to 10 seconds.

One can imagine laboratory experiments and other means to explore these questions, but such experiments do not appear to have been carried out. According to a National Science Foundation (NSF) program officer, NSF does not appear to have a program to address earthquake-induced injuries (David Mendonca, written commun., 8 Dec 2015). Nor does there appear to be a relevant program within the National Institutes of Health.

Acknowledgments

Jamie Jones performed most of the geographic information system analysis employed here. Dale Cox, Marla Petal, and Anne Wein reviewed the work and provided valuable advice; the author thanks all these people for their help.

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Appendix: survey instrument

University of Colorado Boulder

How long does it take to drop, cover, and hold on?

Thanks for following the link to this project entitled *Assessing Earthquake Early Warning (EEW) Self-Protection Reaction Time*.

As a stakeholder in earthquake readiness, please participate in a study that will improve our understanding of personal protective actions for earthquake shaking and the potential value of warning messages about imminent earthquake shaking. By participating you may also improve your ability to protect yourself during earthquakes.

In this research, you will determine your reaction time to drop, cover, and hold on (DCHO). Participation will take approximately 10 minutes.

Procedures: You will be asked to 1) read brief written instructions and watch two short videos about how to drop, cover, and hold on; 2) time yourself performing the drop-cover-and-hold-on actions; 3) complete a questionnaire telling us how long it took to drop, cover, and hold on, where you started from, and assessing the effectiveness of the training. At your own option, you may bring a friend to time and videorecord you performing the drop-cover-and-hold-on exercise, and share the video with the researchers.

Risk: Participation in this study involves no risk to you.

Benefits: This information will help you to better understand how to drop, cover, and hold on, and it will help researchers understanding how much time people need to take appropriate self-protection action when alerted by earthquake early warning.

Voluntary participation: Participation in this study is voluntary. There is no penalty if you choose not to participate.

Confidentiality: Your identity will be kept confidential and will not appear in any report. If you choose to provide an optional video recording, you will upload it to YouTube and only share the link with us. You will set the privacy. We recommend you set the privacy to "unlisted" so that only people who have the link can find and view the video. (If you leave the privacy set to "public," other people can view your video.) We will not download or store your YouTube video, nor will we present it to anyone. We will only view videos to spot check the efficacy of the training and your reaction time. You may delete your video from YouTube any time.

Questions: If you have any questions concerning participation in this study, now or in the future, contact Prof. Keith Porter, University of Colorado Boulder at keith.porter@colorado.edu. If you have questions about your rights as a research study participant, you can call the Institutional Review Board (IRB). The IRB is independent from the research team. You can contact the IRB if you have concerns or complaints that you do not want to talk to the study team about. The IRB phone number is (303) 735-3702, or email irbadmin@colorado.edu.

No participation by vulnerable populations: Members of the following vulnerable populations may not participate: children under 18 years old, people outside the United States, non-English speaking individuals, prisoners, pregnant women, and cognitively impaired or educationally disadvantaged individuals.

Consent to participate: I have read all of the above information about this research project and all my questions have been answered. By clicking "Agree to participate" I confirm that I am not a member of a vulnerable population and I consent to take part in the study.

- ○ I agree to participate. (The button will guide you through the study.)
- ○ I decline to participate.

Thanks for agreeing to participate in this study of the time it takes to drop, cover, and hold on. Please read this training material, then watch the videos below.

Drop, Cover, and Hold On when the earth shakes.

Taking the proper actions, such as "Drop, Cover, and Hold On", can save lives and reduce the risk of injury. Everyone, everywhere, should learn and practice what to do during an earthquake, whether you're at home, work, school or traveling.
In MOST situations, you will reduce your chance of injury if you:

- **DROP down onto your hands and knees** (before the earthquakes knocks you down). This position protects you from falling but allows you to still move if necessary.
- **COVER your head and neck** (and your entire body if possible) under a sturdy table or desk. If there is no shelter nearby, only then should you get down near an interior wall (or next to low-lying furniture that won't fall on you), and cover your head and neck with your arms and hands.
- **HOLD ON to your shelter** (or to your head and neck) until the shaking stops. Be prepared to move with your shelter if the shaking shifts it around.

Official rescue teams, emergency preparedness experts, and others recommend "Drop, Cover, and Hold On" as the best way, in most situations, to protect yourself during earthquake shaking.
In general, it is important to think about what you will do to protect yourself wherever you are if an earthquake were to occur. What if you are driving, in a theater, in bed, at the beach, etc.? Read below for suggestions for these and other situations.

During earthquakes...

The area near the exterior walls of a building is the most dangerous place to be. Windows, facades and architectural details are often the first parts of the building to collapse. To stay away from this danger zone, stay inside if you are inside and outside if you are outside.

Indoors: Drop, cover, and hold on. Drop to the floor, take cover under a sturdy desk or table, and hold on to it firmly. Be prepared to move with it until the shaking stops. If you are not near a desk or table, drop to the floor against the interior wall and protect your head and neck with your arms. Avoid exterior walls, windows, hanging objects, mirrors, tall furniture, large appliances, and kitchen cabinets with heavy objects or glass. Do not go outside!

In bed: If you are in bed, hold on and stay there, protecting your head with a pillow. You are less likely to be injured staying where you are. Broken glass on the floor has caused injury to those who have rolled to the floor or tried to get to doorways.

In a high-rise: Drop, cover, and hold on. Avoid windows and other hazards. Do not use elevators. Do not be surprised if sprinkler systems or fire alarms activate.

Outdoors: Move to a clear area if you can safely do so; avoid power lines, trees, signs, buildings, vehicles, and other hazards.

Driving: Pull over to the side of the road, stop, and set the parking brake. Avoid overpasses, bridges, power lines, signs and other hazards. Stay inside the vehicle until the shaking is over. If a power line falls on the car, stay inside until a trained person removes the wire.

In a stadium or theater: Stay at your seat and protect your head and neck with your arms. Don't try to leave until the shaking is over. Then walk out slowly watching for anything that could fall in the aftershocks.

Near the shore: Drop, cover, and hold on until the shaking stops. Estimate how long the shaking lasts. If severe shaking lasts 20 seconds or more, immediately evacuate to high ground as a tsunami might have been generated by the earthquake. Move inland 3 kilometers (2 miles) or to land that is at least 30 meters (100 feet) above sea level immediately. Don't wait for officials to issue a warning. Walk quickly, rather than drive, to avoid traffic, debris and other hazards.

Below a dam: Dams can fail during a major earthquake. Catastrophic failure is unlikely, but if you live downstream from a dam, you should know flood-zone information and have prepared an evacuation plan.

Now, please watch these two videos, and then click "Next." Each video will open a new browser window or tab. When done, navigate back to this one.

1. If you are near a study desk or table

2. If there is no sturdy desk or table.

For the next step, either do it yourself or optionally bring a friend with a smartphone or a videocamera. Either way, bring a digital watch or a watch with a second hand to a place where you would commonly be on a weekday afternoon at 2 PM. Don't go any place where it will be dangerous or illegal to drop, cover, and hold on, either for you to do or for your friend to time and record you.

If you brought a friend, have the friend start a videorecording, hold the watch, and tell you "Ready set go."

The time *starts* when your friend says go, or if you didn't bring a friend, when you start to drop.

If you do *not* get under shelter, the time *stops* when you have covered your head and neck. If you *did* get under cover, the time *stops* when you have held on to the shelter.

How long did it take, from start to stop, in seconds? Please enter a number only. For example, if it took 10 seconds, enter the numbers 10 or 10.0.

Which of the following best describes the setting where you timed yourself. Please mark only one answer.

Residence

- Single family dwelling
- Mobile home
- Apartment or condominium
- Hotel or motel
- Group housing (military or college) or jail
- Nursing home

Commercial establishment

- Store
- Warehouse
- Shop or service station
- Professional or technical services office
- Bank or financial institution
- Hospital
- Medical office or clinic
- Entertainment or recreation (for example, a restaurant or bar)
- Theater
- Parking lot or garage

Industrial facility

- Heavy industry
- Light industry
- Food, drugs, or chemical factory
- Metals or minerals processing
- High technology factory
- Construction office

Agriculture

- Agricultural facility, such as a farm or ranch

Religion or nonprofit

- Church, mosque, synagogue, food pantry, or other nonprofit

Government

- General services, such as a government office
- Emergency response, such as a police or fire station

Education

- School (pre-K to 12)
- College or university, other than dormitory

Optional: upload your video to Youtube, set the privacy to "unlisted," and paste the link to the video below. (Instructions on how to upload videos are here. A new browser window or tab will open. When done, navigate back to this one.)

Assessment of the instructional materials

The instructions I read and videos I viewed helped me realize the importance of taking appropriate self-protective actions in the event of strong shaking from an earthquake. (Please mark only one answer.)

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

The instructions I read and videos I viewed made clear to me what to do if strong shaking occurs from an earthquake in most cases. (Please mark only one answer.)

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

In the event of strong shaking from an earthquake, in most situations my self-protective actions should be: (Please mark only one answer.)

- ○ Find an area outside that is clear of power lines and trees and go there
- ○ Drop to the floor, cover my head and neck under something sturdy, and hold on to the sturdy furniture or to my head and neck.
- ○ Find an evacuation route and drive to a place of safety as directed by emergency managers.
- ○ Take cover near an exterior wall that doesn’t have any windows.

The instructions I read and videos I viewed made clear to me what to do if strong shaking from an earthquake occurs while I am in bed. (Please mark only one answer.)

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
◯	◯	◯	◯	◯

In the event of strong shaking from an earthquake while I am in bed, my self-protective actions should be: (Please mark only one answer.)

◯ Find an area outside the building that is clear of power lines and trees and go there.

◯ Drop out of bed to the floor, cover my head and neck under something sturdy, and hold on to the sturdy furniture or to my head and neck.

◯ Stay in bed, hold on, and protect my head with a pillow.

◯ Take cover near an exterior wall that doesn’t have any windows.

The instructions I read and videos I viewed made clear to me what to do if strong shaking from an earthquake occurs while I am in a high-rise building. (Please mark only one answer.)

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
◯	◯	◯	◯	◯

In the event of strong shaking from an earthquake while I am in a high-rise building, my self-protective actions should be: (Please mark only one answer.)

◯ Take the stairs to the first floor, get out of the building, and move to an area outside that is clear of power lines and trees.

◯ Drop to the floor, cover my head and neck under something sturdy, and hold on to the sturdy furniture or to my head and neck.

◯ Take the stairs to the first floor, get out of the building, and drive to a place of safety as directed by emergency managers.

◯ Take cover near an exterior wall that doesn’t have any windows.

The instructions I read and videos I viewed made clear to me what to do if strong shaking from an earthquake occurs while I am outdoors. (Please mark only one answer.)

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

In the event of strong shaking from an earthquake while I am outdoors, my self-protective actions should be: (Please mark only one answer.)

- ○ Find an area that is clear of power lines and trees and go there.
- ○ Find a building to go into and the drop to the floor, cover my head and neck under something sturdy, and hold on to the sturdy furniture or to my head and neck.
- ○ Find an evacuation route and drive to a place of safety as directed by emergency managers.
- ○ Stay where I am and drop to the ground, cover my head and neck, and hold onto a tree or some other sturdy object.

The instructions I read and videos I viewed made clear to me what to do if strong shaking from an earthquake occurs while I am driving. (Please mark only one answer.)

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

In the event of strong shaking from an earthquake while I am driving, my self-protective actions should be: (Please mark only one answer.)

- ○ Find an area that is clear of power lines and trees and go there.
- ○ Pull over to the side of the road, stop, set the parking brake, and stay inside the vehicle.
- ○ Pull over to the side of the road, stop, and set the parking brake. Get out of the vehicle and drop to the ground, cover my head and neck, and hold on.
- ○ Find an evacuation route and drive to a place of safety as directed by emergency managers.

The instructions I read and videos I viewed made clear to me what to do if strong shaking from an earthquake occurs while I am in a stadium or theater. (Please mark only one answer.)

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

In the event of strong shaking from an earthquake while I am in a stadium or theater, my self-protective actions should be: (Please mark only one answer.)

- ○ Find an area outside that is clear of power lines and trees and go there.
- ○ Drop to the floor, cover my head and neck, and hold on to the seat or to my head and neck.
- ○ Find an evacuation route and drive to a place of safety as directed by emergency managers.
- ○ Stay in my seat and protect my head and neck with my arms.

The instructions I read and videos I viewed made clear to me what to do if an earthquake occurs while I am near the ocean shore. (Please mark only one answer.)

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

In the event of strong shaking from an earthquake when I am near the ocean shore, my self-protective actions should be: (Please mark only one answer.)

- ○ Find an area that is clear of power lines and trees and go there.
- ○ Drop to the ground, cover my head and neck, and hold on to my neck and head until the shaking stops. Then evacuate to high ground.
- ○ Find an evacuation route and drive to a place of safety as directed by emergency managers.
- ○ Find a nearby building. Go inside and drop to the floor, cover my head and neck, and hold on to something sturdy.

The instructions I read and videos I viewed made clear to me what to do if an earthquake occurs while I am downstream from a dam. (Please mark only one answer.)

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

In the event of strong shaking from an earthquake when I am downstream from a dam, my self-protective actions should be: (Please mark only one answer.)

○ Find an area outside the building that is clear of power lines and trees and go there.

○ Stay inside. Drop to the floor, cover my head and neck under something sturdy, and hold on to the sturdy furniture or to my head and neck.

○ Know the flood-zone information and proceed to evacuate the area if a warning to do so is issued.

○ Know of higher ground and proceed to the highest ground in the flood-zone area.

Based on the instructions I read and videos I saw, I am confident that I would take appropriate self-protective actions if strong shaking from an earthquake occurs. (Please mark only one answer.)

Strongly Disagree	Disagree	Neither Agree nor Disagree	Agree	Strongly Agree
○	○	○	○	○

What if anything did you find particularly helpful in the written or video instructional materials?

What if anything do you believe would make the written or video instructional materials more helpful?

Demographic questions, to check how representative respondents are of the general population.

What year were you born?

What is your gender?

- Male
- Female

Which of the following best describes your race or ethnicity? (Check all that apply.)

- White/Caucasian
- African American
- Hispanic
- Asian
- Native American
- Pacific Islander
- Other

What is the highest level of education you have received?

- Less than High School

- High School / GED
- Some College
- 2-year College Degree
- 4-year College Degree
- Masters Degree
- Doctoral Degree
- Professional Degree (JD, MD)

What is your combined household income?

- under $20,000
- 20,000-29,999
- 30,000-39,999
- 40,000-49,999
- 50,000-59,999
- 60,000-69,999
- 70,000-79,999
- 80,000-89,999
- 90,000-99,999
- 100,000-109,999
- 110,000-119,999
- 120,000-129,999
- 130,000-139,999
- 140,000-149,999
- 150,000+

You are done! Thank you for responding. If you have any other important comments, enter them here. Please be sure to press the "Next" button.