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# Anticipated behavioral response patterns to an earthquake: The role of personal and household characteristics, risk perception, previous experience and preparedness

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ABSTRACT

Earthquakes pose a serious threat to human health and well-being. The interaction between human-related factors such as choice of protective behavioral strategy, on one hand, and the built environment, on the other, may exacerbate or mitigate the aftermath of a given quake event. This study surveyed expected behavioral strategies among residents of a high vulnerability risk area in Israel and assessed factors that could influence their behavior. The results demonstrate that residents with low socioeconomic status are more vulnerable. Several personal and socioeconomic characteristics are associated with residents' expected behavior. Levels of earthquake preparedness and dwelling type are significant predictors of choice of a recommended behavioral strategy. The implications of these results and possible ways to improve preparedness are discussed.

## 1. Introduction

The strong earthquake that struck Nepal in April 2015 and claimed the lives of more than 9000 people was just the latest in a series of lethal events over the last decade demonstrating that earthquakes have been the single deadliest natural disaster worldwide [14]. However, independently of the character of the seismic event itself (e.g. its magnitude), these earthquakes seem to have had significantly different impacts in different parts of the world. Countries that implemented strict seismic building codes, strengthened existing structures and took measures to increase the population's preparedness tended to suffer less severe consequences than those that did not (usually developing countries). A recent example supporting this argument is provided by two earthquakes that took place in 2010 and were very similar in micro-seismic parameters, such as magnitude, depth, and distance of the epicenter from large population centers: the magnitude 7.0 New Zealand earthquake resulted in two injured individuals and no fatalities, while the Haiti earthquake (also magnitude 7.0) had a catastrophic aftermath – more than 300,000 fatalities and a similar number of injuries [64]. It is well documented that poor standards of building construction and damage to the built environment are the main causes of injury and death in earthquakes worldwide [27,28,43,45,48]. However, additional factors, such as personal and household characteristics, are recognized as potential contributors to vulnerability [11,56,58]. Population behavior is another such factor. However, the question of how to act during an earthquake is complex and the answers are inconclusive. Currently, there is no unified recommendation regarding appropriate behavior when an earthquake strikes. Two main but divergent behavioral strategies are recommended around the world to persons who find themselves inside buildings: a) shelter inside the structure, usually through "drop, cover and hold"; or b) evacuate the structure to an open area [16]. The reason for this divergence is related to differences in the vulnerability of structures to earthquake hazards (e.g. ground shaking) and in the threats they pose to their occupants. In regions where most of the building stock is seismically designed and can withstand earthquakes (usually in developed countries), the main hazard to occupants is from falling objects (e.g. furniture, electrical or mechanical components, etc.), which can cause injury and even death [40,52,57]; in such cases, the "drop, cover and hold" strategy is preferable since it provides protection from this hazard. However, where the building stock is of poor quality or not reinforced to meet seismic codes, the main threat to occupants is from collapse of the structure [24]. This is common in developing countries, but also characterizes old and historic buildings and neighborhoods in developed countries, and is unfortunately evident in countries where public sector and building industry corruption is widespread [13,3]. In such situations the

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prevailing recommendation is to evacuate immediately to avoid the dangers posed by structural damage, among them being trapped under rubble [4,22,53]. As noted above, currently there is no"one size fits all" recommendation regarding behavior during an earthquake, and the effectiveness of each strategy must be assessed individually by each country or state in light of the characteristics of the local built environment.

The State of Israel is located along the Dead Sea Fault, a locus of intensive seismic activity; over a span of two thousand years, hardly any city in the area has been spared the effects of tremors. The last major and devastating earthquake (Ms = 6.2) struck our region in 1927 - 90 years ago, causing extensive damage and hundreds of fatalities [5]. According to historical records the recurrence time for magnitude 6 earthquakes is ~100 years [18]. Thus, experts believe that strong quakes are certain to occur in the near future, placing the population at risk ([32] and references therein). Numerous studies demonstrated the expected seismic effects in various areas in Israel (i.e. ground shaking amplification, slope failure, and tsunami) that may cause substantial damage to infrastructure and property, and casualties ([32,33] and references therein). The outputs from these investigations were included in Israel's national emergency drills in 2012 [33], and 2017 [60] that were dedicated to manage the impacts of a severe earthquake. The danger is particularly acute because a large proportion of the structures in Israel are not properly earthquake resistant [44]. Therefore, the prime recommended behavior during an earthquake is to evacuate to an open area, or, if that is impossible (e.g. for residents of upper stories), to shelter inside the structure in the nearest staircase (staircases are considered seismically resistant if built post 1980, when a seismic construction code was applied in Israel) or in the apartment's bomb shelter [22].

Human behavior is difficult to predict at all times and even more so during emergencies, which are stressful, chaotic events [63]. Several theoretical frameworks have been proposed in an effort to understand human behavioral response to threats (whether environmental or in other health-related emergencies). The "Protection Motivation Theory" [15,54] and the "Person Relative to Event" approach [41] propose that people engage in self-protective behavior based on their perceived appraisal of the risk and on their evaluation of their resources as sufficient (response-efficacy and self-efficacy) in relation to the threat. The "Protective Action Decision Model" [37] addresses the issue of human behavior in disasters (e.g. natural hazards), but refers more to preparedness-related behavior or response to an ongoing event and often deals with the issue of evacuation from a risk area. This third model suggests that factors such as risk appraisal and perceived efficacy of protective measures and resources influence individual decision-making processes and responses. Risk appraisal encompasses the perceived expectations of individuals regarding the probability and severity of the hazard, its imminence, the extent of personal impact (e.g. physical injury, property damage and disruption to daily routine), and also the rate of concern about the hazard [34]. Risk perceptions were found to be correlated with implementation of seismic adjustments (actions to mitigate potential consequences to people and property) [36] and also with immediate behavioral response patterns during earthquake events [38].

The "Social Attachment Model" [39] deals with immediate response to disastrous events and proposes that individuals are more likely to seek the proximity of a familiar person during a disaster rather than to evacuate, but this tendency was not uniquely attributed to earthquakes. Studies that examined individuals' immediate responses during an earthquake concluded that the decision-making process is conscious, rational and adaptive [17,51]. Escaping buildings during a tremor was found to be a frequent type of response by occupants even in countries where this type of behavior is considered inappropriate; in several unrelated studies up to a third of participants were reported to act in this manner [1,38,49,50].

Previous studies in the field of disaster sociology and epidemiology indicate that disaster vulnerability is affected by personal, household, and also community characteristics. In a meta-analysis that assessed risk factors for earthquake-induced injury and death using data from earthquake events spanning 20 years, increased risk was found among women, the elderly and children, physically disabled individuals, and low socioeconomic status populations [56]. One explanation for this finding is that certain populations have a lower propensity to take preparedness measures or to adopt protective behavior strategies during a disaster (for example, evacuating a collapsing building) [10,69]. However, the evidence in the literature in this regard is inconclusive [21,34,6], and further research is needed. Disaster preparedness (and thus, also vulnerability) may also be affected by sociocultural differences related to people's previous experience, beliefs, and attitudes toward a certain hazardous event [47]. Studies that have conducted cross-cultural comparisons among communities that have previously experienced earthquakes, such as in New Zealand, Japan, and Taiwan, identified common predictors of earthquake preparedness that can be applied in a multinational social resilience policy [29,46,7]. Nevertheless, this issue is less investigated among communities in which earthquakes are less frequent, yet still pose a serious threat to the population, such as in Israel.

Current global trends, such as population growth, increased life expectancy, migration and rapid urbanism, have resulted in a significant increase in the number of persons residing in dense urban centers. Urban settings display unique vulnerabilities to disaster as compared with smaller or rural communities [10]. Residents of a multistory building have only limited escape routes available to them if the structure is damaged in an earthquake; this can multiply the number of casualties and of persons entrapped under rubble, as was demonstrated in numerous events [59]. Seismic building design and structural strengthening methods are constantly being updated and improved, but implementation is very costly. As a result, a substantial percentage of a growing city's building stock (especially in relatively poor or historic parts) may remain highly vulnerable. The convergence of socioeconomic vulnerability and environmental inequality can further exacerbate the negative consequences of a disaster [9]. This explains why impoverished individuals, households or even entire communities are particularly vulnerable [26,62], as demonstrated in the catastrophic earthquake that struck near Port-au-Prince in 2010.

Other factors, such as previous experience with disasters or emergencies (e.g. number of earthquakes experienced, or experience of earthquake losses by a person or his significant others) and implementation of preparedness measures, have also been found to be correlated with population behavior during a disaster; however, results regarding the direction of these correlations have been inconclusive. While some evidence suggests that previous emergency or disaster experience can motivate people to adopt desirable behavioral strategies (e.g. evacuation prior to a hurricane or exiting a building during an earthquake) [67], other reports indicate a contrary effect, sometimes referred to as the experience-adjustment paradox, thought to occur when less-destructive events lead to a "false experience" perception [6]. Either way, the notion of previous personal experience as predictor of behavior has yet to be validated and will have to be further investigated [2,34,35].

Earthquake hazard adjustments, including the implementation of preparedness measures to improve resilience and response capacities, were found to be positively related to hazard awareness. These adjustments range from purchasing insurance, strengthening residential structures, and stockpiling supplies such as food, water and medications, to bracing heavy objects to walls [34]. One can assume that individuals who are highly aware and as a result are better prepared for an earthquake will also be more familiar with immediate response recommendations (e.g. behavioral strategies) and will hopefully act accordingly during the quake. That this is so was confirmed in a study that examined immediate behavioral response patterns of individuals in New Zealand and Japan to two earthquake in 2011; a positive