GENDER DEPENDENT PERCEPTION OF EARTHQUAKE EFFECTS

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ABSTRACT :

This paper addresses the question of whether or not the perception of earthquake effects is gender dependent. The case considered is the South Iceland earthquake sequence of June 2000. This includes two moderate sized shallow strike-slip earthquakes with high peak ground acceleration in the epicentral area. After the earthquakes a survey on earthquake intensities was carried out by the Earthquake Engineering Research Centre of the University of Iceland. The survey also included questions addressing safety issues, as well as demographic information. The data dealt with herein cover a total of 249 respondents in the epicentral area. In the analysis presented the main emphasis is on the following three questions. Did you manage to seek shelter inside a house during the earthquake? Did you manage to keep your balance? How long did it take for you to recover? The main finding is that the data indicate a tendency towards gender dependent earthquake perception, which in some cases appears to be a statistically significant.

KEYWORDS: Earthquake intensity, strong-motion, survey, earthquake perception

1. INTRODUCTION

Iceland is known as an earthquake-prone country with a history of damaging earthquakes that goes far back in time. Even though earthquakes have caused widespread damage through the centuries, the number of deaths due to earthquakes is small, roughly one hundred fatalities during the last millennium. The seismic activity in Iceland is attributed to the boundary of the diverging North American and the Eurasian tectonic plates. A shift in this boundary results in two major transform or fracture zones in Iceland, one in the south, the South Iceland Seismic Zone (SISZ), and one in the north, commonly called the Tjornes Fracture Zone. All major damaging earthquakes in Iceland have originated within these two zones. Outside these two major earthquake areas, there is significant seismic activity that is most commonly related to the spreading axes and to volcanoes.

In the South Iceland Lowland the historic earthquakes of 1896, along with the destructive 1912 earthquake, are the most noteworthy instrumentally recorded events. A detailed description of the damaging effects of the 1896 earthquakes adds to the value of the recordings. A damaging South Iceland earthquake sequence comparable to the 1896 earthquakes occurred in June 2000. The sequence began at 15:41 on 17 June 2000, with a magnitude 6.5 earthquake whose epicentre was just north of the rural village of Hella. It was followed by major seismic activity throughout the entire SISZ and the Reykjanes Peninsula. The second earthquake in the sequence that exceeded magnitude 6 occurred on 21 June at 00:52. The magnitude was 6.4 and the epicentre was approximately 17 km west of the epicentre of the first event.

The June 2000 earthquake-induced damage was widespread. However, the major damage was mostly limited to the epicentral region of the two biggest events. The elliptically shaped damage areas around the main causative faults stretch out towards the north and south of the epicenters. It should be noted that the margins of the damage areas are less than 20 km from the causative faults. A significant proportion of the damage in the first earthquake occurred in the rural village of Hella situated no more than 5 km from the southern end of the causative fault. The second earthquake also caused a great deal of damage to buildings in the epicentral area, but this was mostly confined to individual farms, groups of summer cottages and utility and communication systems. Considerable damage was caused to equipment, household articles and objects inside buildings, both in the case of residential dwellings and commercial premises. It is worth noting that very heavy objects moved out of place, slid or toppled, indicating that the horizontal as well as vertical acceleration was considerable. This is a finding that is fully supported by accelerometric recordings from the Icelandic Strong Motion Network. Details and individual recordings are available on-line (Ambraseys et al., 2004, to obtain data, see, http://www.ISESD.hi.is).

No serious injuries occurred during the earthquakes, but many things indicate that good fortune had a great deal to do with this (Akason, Ólafsson and Sigbjörnsson, 2006a and b). In this context it is worth pointing out that the first earthquake occurred on Iceland's National Day, 17 June, when many people were gathered outdoors or in well-built assembly houses. Several people suffered minor injuries but no one was seriously hurt. Based on historical evidence the 21 June event was expected and people had prepared for it, for instance by fixing or removing indoor objects that could fall or topple and cause danger to occupants.

The objective of the presented study is to address the question of whether or not perceived earthquake effects are gender depended. This is achieved by using the June 2000 earthquake recordings along with survey data obtained in the wake of the earthquakes.

2. METHODOLOGY, RESEARCH AREA AND SAMPLE

The elements of the model applied in the earthquake effects analysis are summarised in Figure 1, in a simplified way, indicating three basic variable groups. These distinct variable groups are: (1) Seismic variables containing information on the earthquake and the propagation of seismic waves from the source to the site. Here the basic variables are earthquake intensity quantified using the Modified Mercally Intensity, MMI, scale (see, for instance, Wood and Neuman, 1931), the peak ground acceleration quantified as a fraction of the acceleration of gravity (g) and distance from source to site given by the shortest distance to causative fault (rather than the epicentral distance). (2) Built environment variables containing information on building types, building material, building age and location. (3) Human or 'individual' variables referring to the individual person. In this study the basic variables in this group are gender, age and location. The objective of the modelling process is to relate state variables, termed herein the derivative variables, to the basic variables through quantitative models to enhance the understanding of the underlying processes.

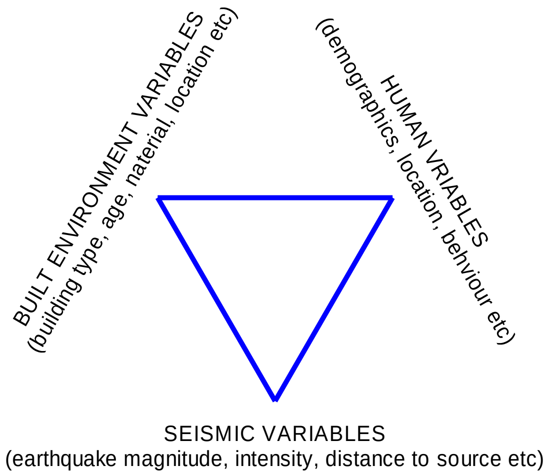


Figure 1 Elements of the earthquake effect analysis represented as a triangle indicating the three basic variable groups.

The application of the MMI scale was an attempt to preserve continuity with earlier studies and in recognition of the fact that the bulk of the intensity data collected in Iceland so far are according to the MMI scale. However, the survey also included information making it possible to obtain intensities according to the European Macroscopic Scale (EMS) (Grünthal, 1998; Musson, 2000). The numerical values did not seem to be much different.

The research area is defined by a borderline at a distance of 20 km from the causative fault of each event. Within this area the mean value of the srss peak ground acceleration is 0.59 g, the standard deviation 0.28 g, the minimum value 0.21 g and the maximum value 1 g. The obtained earthquake intensity, applying the MMI scale, is in the range of IV to X reflecting great variability, as do the strong-motion recordings. The earthquake intensity is a holistic measure of the earthquake action and perceived effects. In an earlier study it was found that the earthquake intensity measure (MMI) correlates better with direction independent quantities, describing the total seismic action, than with the individual acceleration components. Such quantities are, for example, the srss-value, as mentioned above, and the first invariant of the Arias intensity tensor (Sigbjörnsson, Ólafsson and Snaebjörnsson, 2007).

The sample of the population was derived from a random selection of 168 residential buildings augmented by houses hosting strong-motion stations. In all cases the dwellings are low-rise, single-family houses located in rural areas. The construction materials are cast-*in-situ* concrete, timber and masonry. The sample of houses was also selected to ensure that it would reflect fundamental geographical and structural qualities with regard to the nature of the building stock in the area. These included: (1) geographical distribution; (2) age distribution; and (3) distribution of building types and building materials. The foundation conditions are judged to be rock or firm soil in most cases. The basic information on the informants are summarised in Table 1. In all cases emphasis was placed on respondents that were inside houses during the earthquakes.

3. SURVEY

In the presented study a questionnaire survey was applied with emphasis on perceived earthquake intensity, location (i.e. the distance to causative faults), respondent's sex and age, as well as where they were when the earthquakes struck.

In addition, the analysis addresses explicitly the following safety related questions dealt with in the following:

- ✓ Did you manage to seek shelter inside a house during the earthquake?
- ✓ Did you manage to keep your balance?
- ✓ How long did it take for you to recover?

The questionnaire was administrated through telephone conversations by reading the questions for the individuals in the pre-selected sample. The earthquake intensity was treated uniformly by applying the MMI scale, which was read for the respondents. The presented survey was carried out two years after the earthquakes.

Table 1 Characteristic values for the age of respondents in the 2002 survey.

	All	Male	Female
Number of respondents	249	122	127
Mean age (year)	54.3	57. 5	51.2
Median age (year)	52	56	48
Standard deviation (year)	14.5	13.7	14.6
Maximum age (year)	87	87	82
Minimum age (year)	23	30	23

4. RESULTS

In the official guidelines issued in Iceland regarding how to act during an earthquake it is recommended that people inside a building seek shelter by 'moving to a safe place'. In view of this it is interesting to look at the response obtained to the question: did you manage to seek shelter inside a house during the earthquake? The options given in the questionnaire were the following five activities: 1 – I did not think of seeking shelter; 2 – I assumed there was no danger and therefore I did not seek shelter; 3 – I sought shelter and I succeeded in seeking shelter; 4 – I could not move; 5 – I judged that moving might have caused injuries. The results are summarised in Figure 2. Here we see that the most frequent male response was not to think of seeking shelter, while the females responded predominantly by seeking shelter. It is also noted that comparable proportions of males and females could not move. The reason for this is partly due to the high acceleration and violent movements in some of the buildings close to the causative faults.

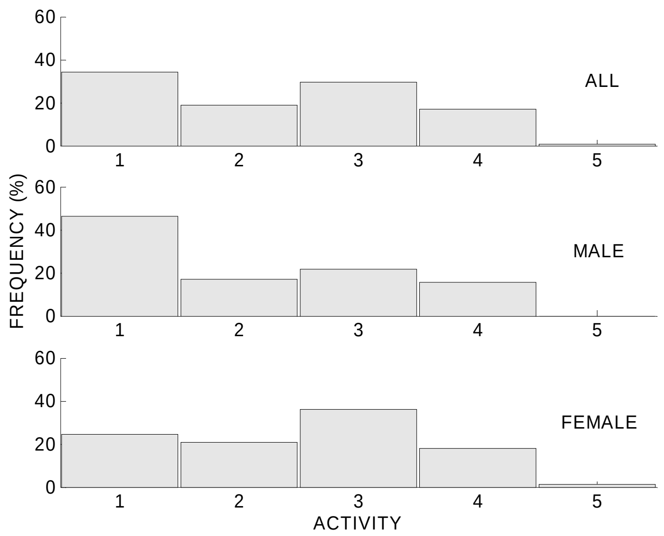


Figure 2 Response to the question: did you manage to seek shelter inside a house during the earthquake? Total number of respondents is 143, number of males is 65 and number of females is 78. Activity scale: 1 – I did not think of seeking shelter; 2 – I assumed there was no danger; 3 – I succeeded in seeking shelter; 4 – I could not move; and 5 – moving might have caused injuries.

A safety related issue is how people manage to keep their balance during the earthquakes and whether or not they fell as a result of the strong motion. An uncontrolled and unexpected fall is a potential threat that may cause injury, which we have examples of from the 17 June earthquake. In view of this observation the subsequent question was phrased: did you manage to keep your balance? The options given in the questionnaire defined the following five activities: 1- I kept my balance; 2 – I was close to falling; 3 – I kept my balance by leaning on something; 4 – I fell; 5 – I was sitting but fell when I tried to stand up; 6 – I was sitting but did not try to stand up. The result of the survey is summarised in Figure 3. It is seen that the female respondents admit falling more often than the males. However, the difference in overall response to this question is not statistically significant at a 5% level.

It is generally recognised that an earthquake is a threatening event that can often have significant psychological stress related effects and traumatic injuries that may take time to heal. Reflecting on this the questionnaire contained the question: how long did it take for you to recover? The options given defined the following simplified time or recovery scale: 1 - I was not scared and I did not need any time for recovery; 2 – I recovered early on; 3 – it took a considerable time to recover; 4 - I have not fully recovered, which implies at least a two year period after the earthquake struck. The results obtained from the survey are displayed in Figure 4. By inspecting the figure it is clearly seen that the females admit more frequently than the male respondents that they have not recovered fully two years after the earthquakes. It is also observed that about 1/3 of the females had not recovered when the survey was carried out in 2002. In this case the response of males and females is statistically different at a 5% significance level.

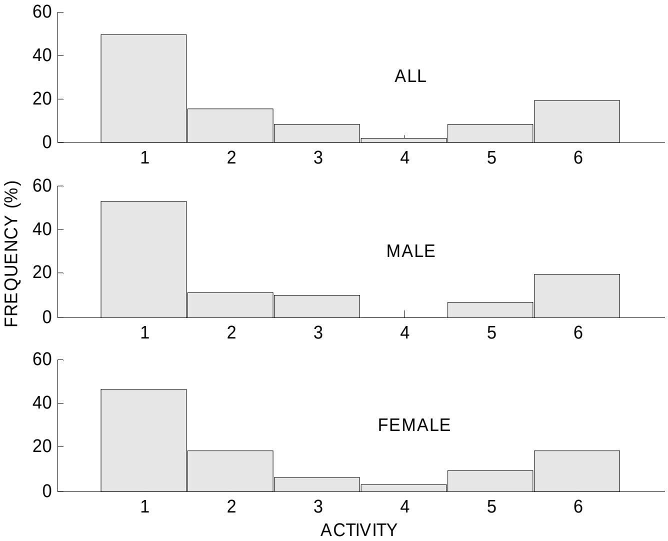


Figure 3 How did you manage to keep your balance? The activity scale: 1- I kept my balance; 2 – close to fall; 3 – kept balance by leaning on something; 4 – I fell; 5 – I was sitting but fell when I tried to stand up; 6 – I was sitting but did not try to stand up. Total number of respondents is 128, number of males is 61 and number of females is 67.

Further analysis of the data reveals a weak but significant correlation between recovery time and earthquake intensity indicated in Figure 5. The overall correlation is about 0.33, slightly higher for the male respondents and somewhat lower for the females. Furthermore, there is a weak positive association between recovery time and age, which implies that older people need a longer time to recover than younger people. The obtained correlation is about 0.25 and statistically significant at a 5% level. In this context is should be stressed that the respondents participating in the survey were all adults (see Table 1). Furthermore, it is worth pointing out that the psychological questions were addressed in another survey (Bödvarsdottir and Elklit, 2004) leading to comparable results.

The results presented above suggest that there might be some gender dependent perception of earthquake effects.

Therefore it was decided to investigate whether or not the assessed earthquake intensities depended on the sex of the respondents. The results of the analysis are displayed in Figure 6 as two overlapping histograms. It is seen that the frequency of intensities above 7 (MII ≥ VII) assessed by the females tends to be bigger than those of the males. On average the mean intensity assessed by females is slightly greater than the mean intensity assessed by males. This difference appears to be statistically significant at a 5% significance level.

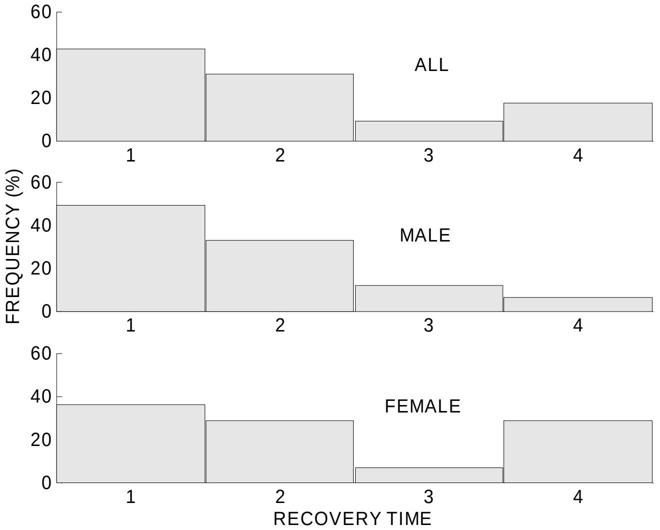


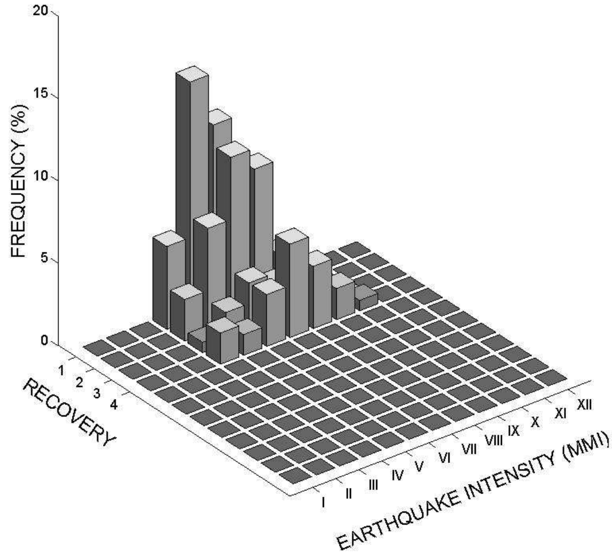
Figure 4 How long did it take for you to recover? Scale: 1 – I was not scared and I did not need any time for recovery; 2 – I recovered early on; 3 – it took a considerable time to recover; 4 – I have not fully recovered (date of the survey). Total number of respondents is 185, number of males is 94 and number of females is 91.

5. CONCLUSION

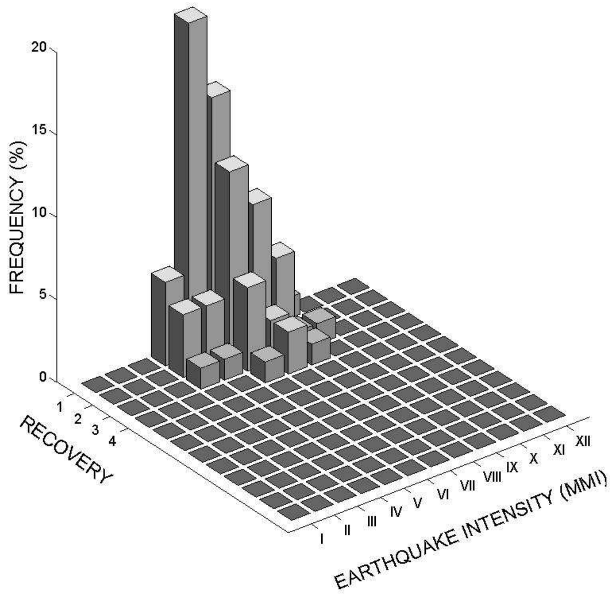
The main finding is that the presented data indicate a tendency towards gender dependent earthquake perception, which in some cases appears to be a statistically significant. This particularly applies to the question 'what to do during an earthquake?' and the time needed to recover psychologically back to normal after the earthquakes. Finally, the earthquake intensities, obtained applying the MMI scale, are found to be gender dependent. The female respondents tend to assess higher MMI values on average than the males. This seems to apply especially to epicentral area where the intensities are highest, i.e. MMI VII or higher. It is not clear whether or not the male assessed earthquake intensities are more correct or more realistic than the female assessed ones. In this context it is, however, worth pointing out that it is a known tendency of the male, being traditionally the physically stronger sex, to play down in hindsight the strength of threatening events or frightening forces. This male characteristic tendency could, hypothetically, lead to an underestimation of earthquake intensities in a survey of the type dealt with herein.

ACKNOWLEDGMENTS

The present work was supported by grants from the University of Iceland Research Fund and RANNIS, the Icelandic Centre for Research. Furthermore, thanks go to the people participating in the survey for their important contribution as well as to the people at the Earthquake Engineering Research Centre administrating the survey.



(a)



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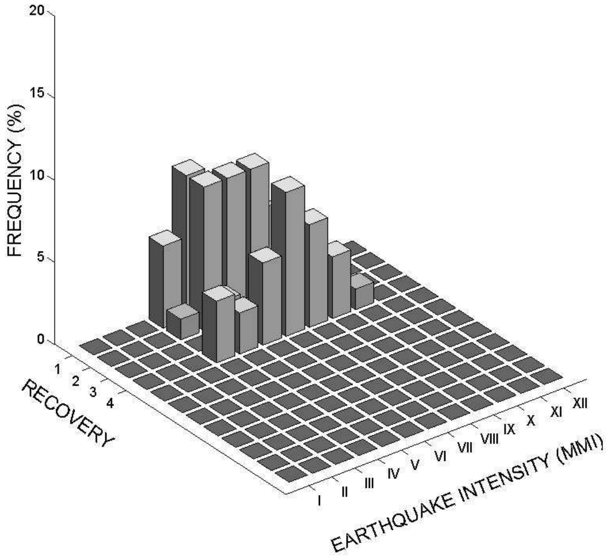

(c)

Figure 5 How long did it take for you to recover? Histogram showing number of respondents as a function of earthquake intensity (MMI) and recovery time (index ∈ {1, 2, 3, 4}). (a) All respondents: correlation between recovery time and earthquake intensity is given by Pearson's r as 0.3273 ($p < 0.0001$). (b) Male respondents: correlation between recovery time and earthquake intensity is given by Pearson's r as 0.3421 ($p = 0.0018$). (c) Female respondents: correlation between recovery time and earthquake intensity is given by Pearson's r as 0.2972 ($p = 0.0070$). Recovery scale: 1 - I was not scared and I did not need any time for recovery; 2 – I recovered early on; 3 - I took a considerable time to recover; 4 - I have not fully recovered (two years after the earthquakes). Total number of respondents is 185, number of males is 94 and number of females is 91.

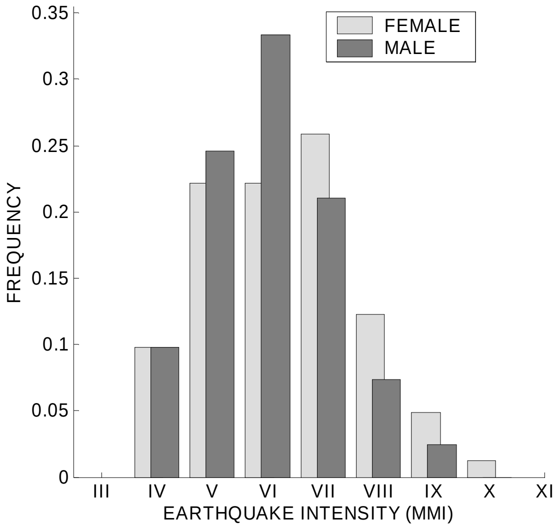

Figure 6 Histogram of perceived earthquake intensities by males and females. Total number of respondents is 161, number of males is 84 and number of females is 76. Mean values are 5.81 and 6.26, respectively, for males and females.

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