THE 2016 KUMAMOTO EARTHQUAKES' INFLUENCE ON RESIDENTS' RISK PERCEPTION

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Abstract

The magnitude 6.2 foreshock on the 14th of April and the magnitude 7.3 main shock on the 16th of April occurred in the 2016 Kumamoto Earthquakes. The main shock over than the magnitude 6.2 was not anticipated because the foreshock was considered to be the main shock. The successive two large shocks increased physical damage but also affected the Japanese risk perception of earthquakes. After the earthquakes occurred, the Japan Meteorological Agency discontinued its policy of announcing the probability of aftershock occurrences. The experience of the 2016 Kumamoto earthquakes and the policy changed concerning risk communication may affect the public risk perception of earthquakes. The study investigates the factors that affected the post-earthquake risk perception. We assumed that the experience of housing damage caused by the earthquakes, pre-earthquake awareness of local faults, and demographics were related to the post-earthquake risk perception.

The study used research data from a mail survey implemented by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) from November 28 to December 19, 2016. Respondents were those who lived in 14 municipalities where the 2016 Kumamoto earthquakes caused severe damage. The number of valid responses was received 3772 (a valid response rate of 46.7%). Male and female valid respondents accounted for 45% and 55%, respectively. The average respondent age was 53.24 (SD = 16.20). The study analyzed data of pre-earthquake awareness of local faults, housing damage (completely destroyed, half-destroyed, partially destroyed, no damage), risk perception of earthquakes (severity, knowledge, uncertainty), and demographics (gender, age).

The study implemented Bayesian generalized linear model analyses to reveal the differences in post-earthquake risk perception between pre-earthquake awareness of local faults, housing damage, and demographics. First, the post-earthquake perception of the severity of earthquakes differed by housing damage. People with completely destroyed and half-destroyed households perceived severity more than people with partially destroyed households and no damage. Second, the main effects of pre-earthquake awareness of local faults, gender, age, and the interaction effect of pre-earthquake awareness × gender on the post-earthquake perception of knowledge of earthquakes were found. Especially, for those with the awareness of local faults, males had more post-earthquake perception knowledge than females, whereas for those without the awareness, females had more post-earthquake perception knowledge than males. Moreover, there was no difference in the post-earthquake perception of the uncertainty of earthquakes between housing damage, demographics, and awareness of local faults.

The study suggested that the three aspects of risk perception of earthquakes were formed by different factors. The perception of severity could be updated by experience suffering from earthquakes. The perception of knowledge could be dependent on demographics and how aware people are of earthquakes. The perception of uncertainty could be formed by intuition, instead of experience and prior awareness of earthquakes. The study discusses the importance of risk communication of earthquakes based on human cognitive mechanisms.

Keywords: awareness of local faults, housing damage, Kumamoto earthquakes, risk communication, risk perception

1. Introduction

The 2016 Kumamoto earthquake was a magnitude 6.2 foreshock and 7.3 mainshock that occurred on April 14 and 16, 2016, respectively. The latter 7.3 shock was not anticipated by most residents because the 6.2 foreshock was considered to be the mainshock at the time. According to the Cabinet Office [1], 270 deaths were reported due to the earthquake in Kumamoto prefecture. Housing damage reports indicated that there were 8,657 completely destroyed, 34,491 half-destroyed, and 155,095 partially destroyed houses. In addition to this serious damage, the two large consecutive earthquakes caused unexpected reactions and actions from residents [2]. For example, different reasons were given with respect to the residents' decisions made during the foreshock and mainshock evacuations. The residents' evacuation patterns influenced the subsequent risk perception of earthquakes. Moreover, the residents' pre-earthquake awareness of local faults was found to relate to their anticipation of aftershock occurrences after the foreshock and mainshock [3]. However, the manner in which residents' experience of the 2016 Kumamoto earthquake impacted their risk perception of earthquakes given their pre-earthquake awareness of local faults is yet to be studied.

Empirical studies in risk perception research aim to examine the psychological process of cognition of risk. According to Slovic [4], risk perception is based on subjective aspects such as "dread" and the "unknown." In addition, risk perception has been considered to be based on two-thinking systems: the first system involves experiential decision-making based on affective experience and intuition (System 1), whereas the second system involves analytic decision-making based on knowledge and rationality (System 2) [5]. Furthermore, a review of risk perception studies of natural hazards has indicated that risk perception can be determined by both direct experience (e.g., experiencing a hazard oneself) and indirect experience (e.g., education and media) [6]. Based on these two-thinking systems, being a victim of an earthquake of can be considered a factor of experiential decision-making of System 1 and one's knowledge of earthquakes can be considered a factor of analytic decision-making of System 2. Moreover, previous studies have indicated that risk perception can be influenced by personal factors such as gender and belief [7, 8]. The present study aims to examine how respondents' experience of housing damage (System 1 factor), pre-earthquake awareness of local faults (System 2 factor), and demographic factors (gender and age) influenced their risk perception after the Kumamoto earthquake.

2. Method

2.1. Survey data

The research data included in the present study was from the "Questionnaire survey and analysis on effect of aftershock information and evacuation actions during the 2016 Kumamoto earthquake," conducted by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) between November 28 and December 19, 2016 by mail [9]. Respondents in the survey lived in the 14 municipalities where the 2016 Kumamoto earthquake caused severe damage. All the municipalities included in the present study met one of the following conditions: (1) Experiencing a mainshock with a seismic intensity of 6+; (2) At least 10% of all houses had totally collapsed (500+ buildings in the districts of Kumamoto City, an ordinance-designated city); (3) At least 20% of houses had partly collapsed; or (4) At least 15% of residents were evacuated.

The municipalities that met these conditions were Higashi-ku and Minami-ku of Kumamoto City, Koshi City, Kikuchi City, Kikuchi-gun (Kikuyo Town and Otsu Town), Kami-Mashiki-gun (Mashiki Town, Kashima Town, Mifune town, and Kosa Town), Uto City, Uki City, Aso City, and Aso-gun (Minami-Aso Town and Nishihara Village).

2.2. Respondents

Male and female adults over 18 were systematically sampled from the poll book or the Basic Resident Registers Network. The original sample number was 7,000, but the number of valid responses was limited to

3,772 (a valid response rate of 46.7%). Male and female valid respondents accounted for 45% and 55%, respectively. The average respondent age was 53.24 (*SD* = 16.20).

2.3. Measurements

In addition to demographic variables (age and gender), earthquake risk perception, pre-earthquake awareness of local faults, and housing damage were also measured in the survey.

2.3.1. Earthquake risk perception

The following three dimensions were included as part of a factor analysis: (1) Severity (α = .91), e.g., serious damage will occur if an earthquake hits this region again and damage will occur in the entire region if an earthquake hits this region again; (2) Knowledge (α = .56), e.g., the scientific understanding of earthquakes is advancing, damage can be minimized if an earthquake hits this region again, and the damage that will be caused by an earthquake is well-known; (3) Uncertainty (α = .64), e.g., an earthquake can occur at any time, an earthquake causes various forms of damage, and the effects of an earthquake can be seen over a long period of time. Items were rated on a five-point Likert scale ranging from 1 (completely disagree) to 5 (completely agree).

2.3.2 Pre-earthquake awareness of local faults

Respondents were asked whether they were aware of the active faults present in their residential area before the earthquakes occurred. Respondents' answers were coded as either "not aware" or "aware."

2.3.3. Housing damage

Respondents were asked whether their house was completely destroyed, half-destroyed, partially destroyed, or had no damage.

3. Result

The score of three dimensions of risk perception (i.e., severity, knowledge, and uncertainty) was shown in Fig. 1. The residents perceived a middle level of knowledge, and they perceived a high level of severity and uncertainty. The study examined the factors influencing the three dimensions of risk perception.

A Bayesian generalized linear model (GLM) was conducted to predict the perception of severity, with gender, age, pre-earthquake awareness of local faults, level of housing damage, as well as interactive terms with pre-earthquake awareness of local faults. The quantitative variables were mean-centered, and the

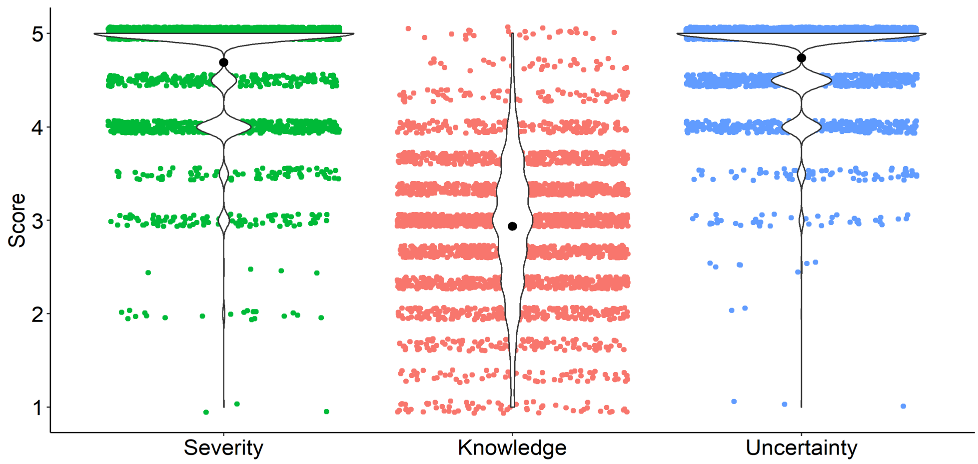

Fig. 1 A violin plot of risk perception scores (severity, knowledge, and uncertainty)
Note: The shape indicates the distribution of data, and the black circular point indicates the average.

Table 1 –Results of the Bayesian GLM of risk perceptions (severity, knowledge, uncertainty)

	Severity						Knowledge						Uncertainty					
	mean	se_mean	sd	95%CI	n_eff	Rhat	mean	se_mean	sd	95%CI	n_eff	Rhat	mean	se_mean	sd	95%CI	n_eff	Rhat
Intercept	4.601	.000	.036	4.530 ~ 4.672	11169	1.000	3.065	.000	.048	2.972 ~ 3.160	12036	1.000	4.759	.000	.030	4.701 ~ 4.817	9800	1.000
Gender(female)	.055	.000	.037	-.019 ~ .127	15001	1.000	-.123	.000	.050	-.222 ~ -.025	16536	1.000	.046	.000	.031	-.015 ~ .107	12964	1.000
Age	.000	.000	.001	-.003 ~ .002	26810	1.000	.003	.000	.002	.000 ~ .006	23803	1.000	-.002	.000	.001	-.004 ~ .000	28810	1.000
Awareness of local active faults(not aware)	-.018	.000	.043	-.102 ~ .064	10800	1.000	-.229	.001	.057	-.340 ~ -.119	11840	1.000	-.061	.000	.035	-.130 ~ .009	9708	1.000
Housing damage(partially destroyed)	.075	.000	.042	-.009 ~ .157	12376	1.000	-.010	.000	.056	-.119 ~ .101	13513	1.000	-.042	.000	.035	-.109 ~ .027	11374	1.000
Housing damage(half-destroyed)	.198	.000	.056	.087 ~ .308	13079	1.000	-.099	.001	.074	-.244 ~ .048	14185	1.000	-.005	.000	.047	-.096 ~ .087	11758	1.000
Housing damage(completely destroyed)	.185	.001	.080	.029 ~ .339	14795	1.000	.197	.001	.107	-.013 ~ .406	16185	1.000	.058	.001	.067	-.075 ~ .192	13832	1.000
Awareness of local active faults × Gender(female)	-.020	.000	.045	-.107 ~ .069	14842	1.000	.211	.000	.060	.093 ~ .329	16416	1.000	-.007	.000	.037	-.080 ~ .065	12502	1.000
Awareness of local active faults ×Age	-.002	.000	.001	-.005 ~ .001	27114	1.000	-.001	.000	.002	-.004 ~ .003	24260	1.000	.000	.000	.001	-.003 ~ .002	28578	1.000
Awareness of local active faults × Housing damage(partially destroyed)	.050	.000	.051	-.049 ~ .150	11994	1.000	.029	.001	.067	-.102 ~ .160	12697	1.000	.044	.000	.041	-.038 ~ .125	11057	1.000
Awareness of local active faults × Housing damage(half-destroyed)	.031	.001	.068	-.104 ~ .164	12723	1.000	.170	.001	.091	-.007 ~ .347	13859	1.000	.045	.001	.056	-.066 ~ .153	11670	1.000
Awareness of local active faults × Housing damage(completely destroyed)	.058	.001	.105	-.146 ~ .260	15553	1.000	-.090	.001	.141	-.368 ~ .190	15773	1.000	-.084	.001	.088	-.256 ~ .089	13754	1.000
sigma	.568	.000	.007	.553 ~ .582	27776	1.000	.746	.000	.010	.727 ~ .766	31220	1.000	.465	.000	.006	.453 ~ .477	24930	1.000
lp__	-2596.656	.028	2.551	-2602.563 ~ -2592.709	8400	1.000	-3373.385	.028	2.579	-3379.396 ~ -3369.358	8364	1.000	-1990.260	.028	2.575	-1996.178 ~ -1986.214	8599	1.000

Note: The interval estimation of coefficients is significant as long as 0 is not included among 95% CI.

qualitative variables were dummy coded. The analysis was performed in R using the brms package [10]. All iterations were set to 10,000, and burn-in samples were set to 5,000, with the number of chains set to four. The value of Rhat for all parameters equaled 1.0, indicating convergence across the four chains. Table 1 summarizes these results. The residents reporting that their house was half-destroyed (b = .20, 95% confidence interval [CI] = .09 ～ .31) or completely destroyed (b = .19, 95% CI = .03 ～ .34) perceived severity higher than residents whose house was either partially destroyed or not damaged (Fig. 2).

A similar Bayesian GLM was conducted to predict the perception of knowledge (Table 1). Male residents were found to have a higher perception of knowledge compared with female residents (b = −.12, 95% CI = −.22 ～ −.03: Fig 3_a). Furthermore, residents with pre-earthquake awareness of local faults were found to have a higher perception of knowledge as compared with residents without pre-earthquake awareness of local faults (b = −.23, 95% CI = −.34 ～ −.12: Fig 3_b). Older residents were also found to have a higher perception of knowledge (b = .003, 95% CI = .000 ～ .01: Fig 3_c). An interaction effect was also found between gender × pre-earthquake awareness of local faults (b = .21, 95% CI = .09 ～ .25: Fig 3_d), where

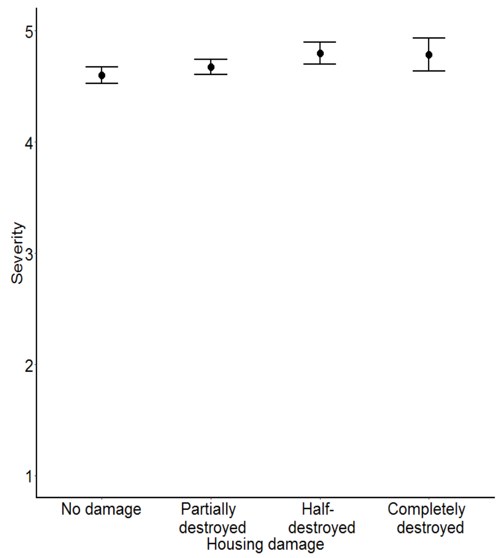

Fig 2 – The plot of the posterior distribution of parameters according to housing damage (severity).

male residents aware of local faults were found to have a higher perception of knowledge compared with female residents, whereas the inverse finding was true for male and female residents without awareness of local faults.

A similar Bayesian GLM was conducted to predict the perception of uncertainty (Table 1), but no effects were found.

4. Conclusion

The severity of risk perception was found to differ in the present study according to the housing damage experienced by residents. The two-thinking systems suggests that negative feeling affects risk perception according to the experiential decision-making of System 1 [5], which is a given, considering they had a horrible experience because of the two consecutive devastating earthquakes in the 2016 Kumamoto earthquake. Respondents whose homes were either half-destroyed or completely destroyed were found to perceive severity more strongly. The perception of severity can be updated by direct experience of earthquakes. This finding supports those of previous studies indicating that people's negative experience of natural hazards influenced their risk perception [6]. The level of physical damage can be an important factor that affects severity.

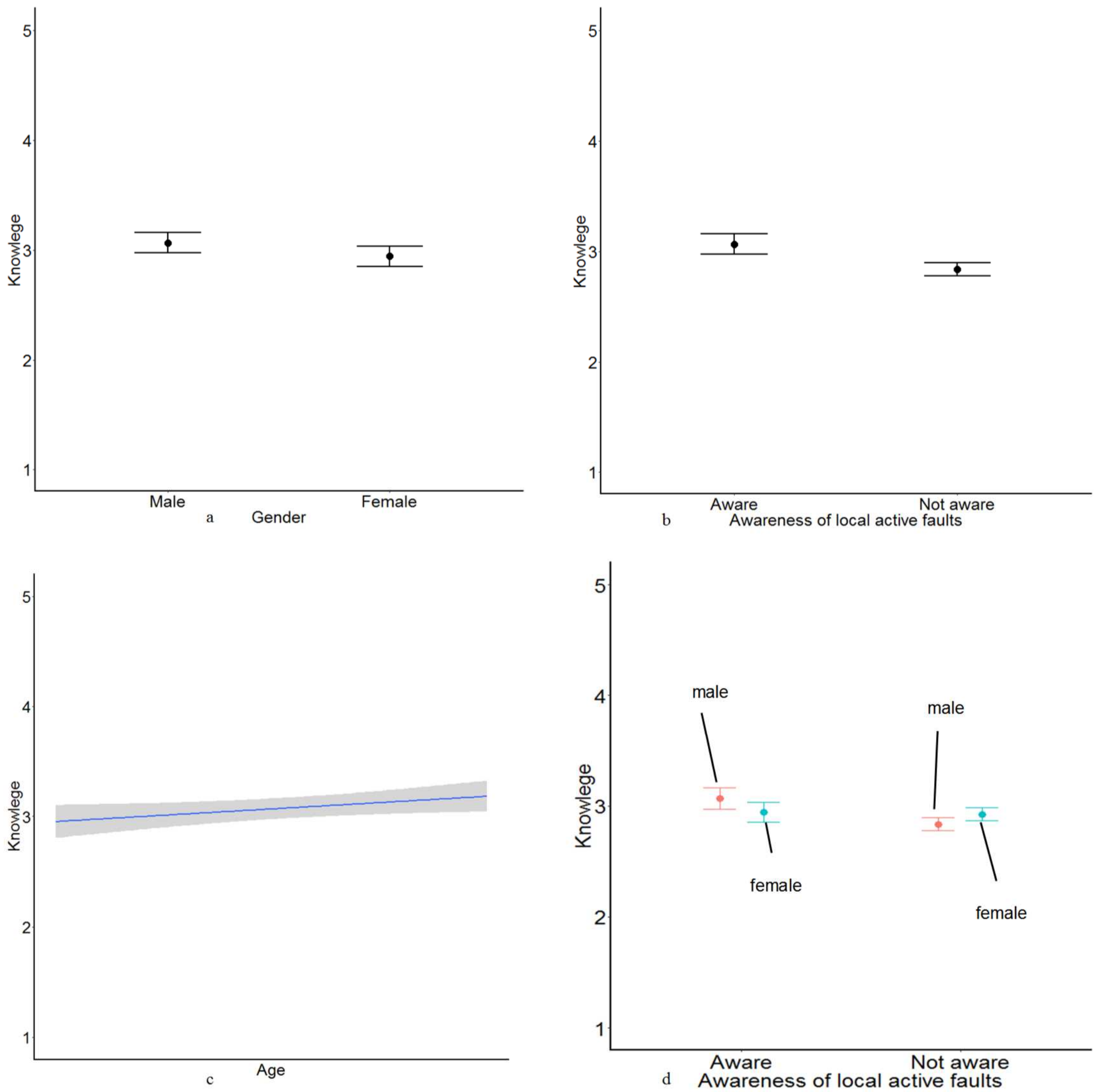

Fig.3 – Plot of the posterior distribution of parameters of housing damage (knowledge).

Concerning the knowledge aspect of risk perception, the findings indicate that the older the residents, the higher their level of perceived knowledge. This finding could be due to the fact that older residents have relatively more direct experience of natural hazards, including earthquakes. In addition to the main effect of pre-earthquake awareness of local faults on the perception of knowledge, the effect was also found to differ by gender. When residents were not aware of local faults, female residents were found to have a higher level of perceived knowledge. Awareness of hazards was also found to affect risk perception according to the analytic decision-making of System 2 [5]. The main effect of pre-earthquake awareness was considered to be a process of System 2. Previous studies indicated that risk perception differed by gender [8]. For example, that women were more concerned with safety and had a higher risk perception than men in situations where awareness and literacy were not made available. When people lack awareness of natural hazards, System 1 of risk perception is based on intuitive processing, and psychological tendencies based on gender are more likely to impact people's knowledge of risk perception.

As for the uncertainty aspect of risk perception, no differences were found according to gender, age, housing damage, and pre-earthquake awareness of local faults. However, residents were found to have a high level of uncertainty in regards to earthquakes. It is possible that, regardless of personal situations, the perception of uncertainty among most residents was likely increased by the 2016 Kumamoto earthquake. Most residents who experienced the two consecutive large earthquakes, had not anticipated the larger mainshock to occur two days after the large foreshock [2]. This could have been influenced by the belief that one cannot experience another catastrophic event so soon after the last event [7]. In this context, the 2016 Kumamoto earthquake was a natural disaster that challenged people's anticipation of risk. Thus, the experience of the earthquake affected residents' perception of uncertainty, regardless of personal situations.

The study included a discussion on the importance of risk communication of earthquakes based on human cognitive mechanisms. The limitation of the current study is that it did not compare the risk perception of residents before and after the 2016 Kumamoto earthquake. For this reason, the effect of the earthquake on residents' risk perception needs to be interpreted carefully. Despite this limitation, the findings of the study suggest that three aspects of risk perception can be influenced: (1) The perception of severity can change according to experience of earthquakes; (2) The perception of knowledge can be influenced by prior awareness of earthquakes; (3) The perception of uncertainty can be influenced by intuitive experiences common to most people.

5. Acknowledgements

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