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The Determinants of Residents' Evacuation Behavior in the Torrential Rain in Western Japan in 2018: Examination of Survey Data of Victims in Okayama Prefecture

Shoji Ohtomo[*1,†], **Reo Kimura**[*2], **Yoshiaki Kawata**[*3], **and Keiko Tamura**[*4]

[*1]Konan Women's University
6-2-23 Morikita-machi, Higashinada-ku, Kobe, Hyogo 658-0001, Japan
[†]Corresponding author, E-mail: s.ohtomo@konan-wu.ac.jp
[*2]School of Human and Environment, University of Hyogo, Hyogo, Japan
[*3]Faculty of Societal Safety Sciences, Kansai University, Osaka, Japan
[*4]Risk Management Office, Headquarters for Risk Management, Niigata University, Niigata, Japan
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The torrential rain (named "the July 2018 heavy rain") from June 28 to July 8 in 2018 resulted in tremendous human and property damage. There were 237 deaths and 7,173 cases of flooding above the floor level. During the torrential rain, the low rate of evacuation behavior of residents in the affected area was also a problem. The Okayama prefecture conducted a mail survey with residents that suffered housing damage caused by the torrential rain (valid sample n = 3,765). The survey measured what residents' awareness and knowledge were of flooding before the torrential rain, residents' prediction of flooding and choice and reason of evacuation behavior during the emergency heavy rain warning and the evacuation order (emergency). This study analyzed the determinants of residents' evacuation behaviors during the torrential rain with the survey data. The results indicated that, although most residents were aware of hazard maps before the torrential rain, few predicted flooding. Most residents were aware of the evacuation shelters and had a prior evacuation plan. However, some residents made no attempt to evacuate, even when their houses were damaged. During the emergency heavy rain warning, feeling a sense of crisis was an important factor to promote evacuation behavior. And, during the evacuation order (emergency), the majority of those who took actual evacuation behaviors was those who were approached by public sectors such as the fire department and the police. Moreover, residents' judgment based on scientific information such as hazard maps and prediction of flooding before the torrential rain had little effect on evacuation behavior during the emergency heavy rain warning and the evacuation order (emergency). Therefore, the study indicates the importance of approaching residents' affective decision-making, instead of relying on rational decision-making, to promote evacuation behavior when people are in unusual situations.

Keywords: flooding, torrential rain in western Japan in 2018, evacuation behavior, hazard map, decision-making

1. Introduction

From June 28 to July 8, 2018, there was a successive supply of warm and very moist air in Japan due to the influence of the East Asian rain front and a typhoon, causing a record of heavy rain throughout a wide area; mainly in western Japan. As a result, this developed into torrential rain in western Japan (the July 2018 heavy rain), which caused tremendous human and property damage. According to the Cabinet Office [1], the July 2018 heavy rain killed 237 people nationwide, of which 66 were in Okayama prefecture and 115 in Hiroshima prefecture. There were 7,173 cases of flooding above the floor level nationwide, of which 1,131 were in Okayama prefecture and 2,119 in Hiroshima prefecture. There were 21,296 cases of flooding under the floor level nationwide, of which 5,446 were in Okayama prefecture and 5,779 in Hiroshima prefecture. Thus, the damages in these two prefectures account for about half-figure of the damage nationwide.

The problem in the July 2018 heavy rain was the low percentage of residents who took evacuation actions; only 22% of residents in Hiroshima city evacuated (including vertical evacuation) [2]. Another survey conducted in Hiroshima city found that 3.3% of residents evacuated in response to an evacuation advisory or an evacuation order [3]. It was also reported that only 0.5% of the total number of evacuation shelters were used in the 23 prefectures, where evacuation advisories and orders were issued [4]. According to a previous study, residents living in areas where evacuation advisories were issued when the 2017 Typhoon #21 hit the areas, only 4.4% of the residents evacuated to shelters, indicating that the rate of following evacuation orders is generally very low [5]. It is important to consider that many residents did not take sufficient action to evacuate during a disaster. In particular, it is required to examine residents' behavior to determine why they chose to evacuate or not during a disaster.

In psychology, two information processing processes, System 1 and System 2, have been hypothesized as risk-related judgment [6, 7]. System 1, which involves experiential decision-making based on affective experience and intuition, is a process in which immediate action is taken, depending on the given situation. System 2, involving rational decision-making based on knowledge and analyses, is a process in which deliberative action is performed based on consideration. It has been pointed out that in an emergency such as the choice of an evacuation behavior in a natural disaster, it is difficult to make a rational decision that is judged over time in normal times [8]. Therefore, decision-making based on System 1 is likely to occur. It has been used as a framework to explain the influence of the experience of evacuation behavior during the Kumamoto Earthquake on the perception of earthquake risk [9], and the consumer's process of hoarding and avoidant purchasing during the Great East Japan Earthquake [10], and it has been indicated that System 1 was preferred in both cases.

A similar process can be assumed for flood disasters such as heavy rains. Risk communication with residents to facilitate disaster prevention measures and evacuation behaviors include the use of hazard maps. The risk assessment based on the hazard map requires the process of System 2. The residents must read the information on what damage may be caused by the natural disaster. The information processing by System 2 requires attention and effort and is therefore rarely performed. A previous study has indicated that residents' judgment on flood disaster risk is not affected by hazard maps information [11]. Also, scientific knowledge on disasters has little relation to disaster preventions [12, 13]. Kimura et al. [14] have reported that more than half of the residents who knew the active faults that cause earthquakes were aware that no earthquake would occur. There is likely a limit in the promotion of evacuation behaviors through scientific information. It is expected that people will not take evacuation action even if they receive disaster warnings. It has also been reported that few residents have taken actual countermeasure actions even after receiving an earthquake early warning (EEW) [15]. People tend to have optimistic biases, by which the risk of disasters is underestimated and they are less likely to take disaster prevention actions [16].

Affective factors such as a sense of crisis are the reason for evacuation behaviors and disaster preventions rather than judgments based on scientific information. A previous study has indicated that the fears experienced due to natural disasters and the perceived threat of disasters related to disaster preventions [17]. It is also pointed out that the sense of vulnerability enhances motivation for flooding countermeasures [18]. A study on severe rainfall disasters in Japan highlighted that fear is more strongly associated with disaster preventions than the prediction of the severity of the disaster [19]. Thus, affective decision-making by System 1 directly triggers countermeasure behaviors against flood disasters. The approach from others has also been pointed out as an important factor facilitating disaster preventions [20]. It has been reported that some who have not taken evacuation measures acted by the approach of their neighbors [9]. Such social networks are considered normative behavior for disaster prevention [16]. Classical psychology has pointed out that people in an ambiguous situation tend to follow authorities without making their own judgments [21]. Previous study has also indicated that those close to people with special needs are more likely to facilitate evacuation during a disaster [22]. Therefore, this study identifies factors of System 1 and System 2 that relate to the psychological reasons why many residents did not take sufficient evacuation action in the July 2018 heavy rain.

Okayama prefecture surveyed residents in areas with severe housing damage from late November to December 2018, approximately five months after the July 2018 heavy rain [23]. According to the Okayama prefecture report [24], the East Asian rain front activity caused the heavy rain in July 2018. From July 5 to 7, 453.0 mm of rainfall were observed in Tomi, Kagamino-cho, and exceeded 300 mm on the Automated Meteorological Data Acquisition System (AMeDAS). In addition, it was observed that water levels in several places exceeded the level of danger. Under such circumstances, from nighttime on July 6 to dawn of the 7th, evacuation advisories or evacuation orders (emergency) were issued in all 27 municipalities in the prefecture. Evacuation orders (emergency) were issued in 17 of the prefecture's municipalities, and as the flooding area expanded due to the collapse of the riverbank, the target area expanded, and the number of evacuees peaked around the morning of the 8th. The Okayama prefecture survey determines residents' predictions of flooding, choices, and reasons for evacuation behaviors during the following stages: before the heavy rains in July 2018, when they became aware of the emergency heavy rain warning, and during the evacuation order (emergency). Therefore, this study discusses how prior knowledge and recognition of disasters, such as residents' awareness of hazard maps before disasters, flood prediction, awareness of evacuation shelters, and the presence of evacuation plans, affect the choice of evacuation behaviors during disasters. In addition to the prior knowledge and recognition of disasters, this study examines how a sense of crisis affects evacuation behaviors. A previous study has indicated out that the determinants of people's responsive actions vary according to the stage of decision-making against disasters [25]. This study analyzes what aspects of decision-making of System 2 factors related to disasters such as prior knowledge and System 1 factors such as a sense of crisis act at what stage.

2. Method

2.1. Survey Data

The survey data of "Questionnaire on Responsive Actions to July 2018 Heavy Rain" conducted by Okayama prefecture was used [23]. The survey was conducted from November 29 to December 20, 2018. It involved residents in three cities and one town in the Takahashi river system in Okayama prefecture (Kurashiki city, Soja city, Takahashi city, and Yakage town) that suffered severe housing damages.

2.2. Respondents

The survey covered a total of 6,644 households registered in the "disaster victim ledger" of Okayama prefecture. Valid responses were $n = 3{,}765$ (Valid response rate of 56.7%). This study used the analysis data of $n = 3{,}196$, excluding missing values. In terms of gender, the respondents of the analysis data were 2,293 males (72%) and 908 females (28%). The age was 62.15 ($SD = 15.79$) years. The length of residence was 28.78 ($SD = 17.85$) years. The number of damaged houses according to the victim's certificates were as follows: 2,595 (82%) for completely destroyed houses, 249 (8%) for massive half-destroyed houses, 292 (9%) for half-destroyed houses, and 19 (1%) for partially destroyed houses.

2.3. Measurements

For demographic variables other than personal attributes and housing damages, refer to the survey report of the Okayama prefecture [23].

2.4. Awareness of Flooding Before the Disaster

The question about the awareness of hazard maps before the disaster was: "Have you ever seen the hazard map (flood damage) of your residential area before the disaster?" The respondents could choose from the following: "I have seen the hazard map (flood damage) and remembered the contents"; "I have seen the hazard map (flood damage) but did not remember the contents"; "I knew the hazard map (flood damage) but I had never seen it"; "I know the word hazard map but I did not know there was one in this area"; and "I did not know the word hazard map."

The question about the flood prediction before the disaster was: "Before the disaster, did you think that your residential area would ever be in a situation where the residents had to evacuate due to flooding?" The respondents could choose from the following: "I thought we would have one soon"; "I thought we would have one in 10 years or later"; "I thought we would have one in the 21st century"; "I did not think we would have floods causing damage"; and "Before the disaster, I did not think that this area would be damaged by a flood."

The question about the awareness of evacuation shelters before the disaster was: "Before the disaster, did you know about the evacuation shelter?" The respondents could choose from the following: "I knew it accurately through public relations, hazard maps, drills, and the like"; "I had guessed its whereabouts"; "I knew we were going to an evacuation shelter, but I did not know where it was located"; and "I did not think I needed to go to an evacuation shelter."

The question about the presence of an evacuation plan before the disaster was: "Did you have a disaster evacuation plan before the disaster?" The respondents could choose from the following: "I had made clear plans on the evacuation method and location of the evacuation shelter"; "I did not make a plan, but had a rough idea on where and how to evacuate"; "I gave little thought to a specific evacuation method and evacuation shelter during a disaster"; and "I did not think that I would need to evacuate during a disaster."

2.5. Prediction of Flooding and Evacuation Behavior During the Disaster

The question about the flood prediction immediately before and at the time of the emergency heavy rain warning and the evacuation order (emergency) was: "At the time (when you heard the information) before the emergency heavy rain warning (the evacuation order (emergency)), did you think "a flood may occur"?" The respondents could choose from the following: "I did not think about anything in particular"; "I thought we would have more rain but I did not think about a disaster"; "I imagined that the heavy rain would cause a disaster but I thought it was just flooding below the floor level"; "I imagined that the heavy rain could cause a disaster and I thought flooding above the floor level would be likely"; and "Other / I do not remember / I do not know." Note that in the analysis, "Other / I do not remember / I do not know," were regarded as missing data.

The question about the evacuation behavior at the time of being aware of the issuance of the emergency heavy rain warning and the evacuation order (emergency) was: "Had you evacuated (including vertical evacuation to the upper level of the house) at the time you were aware of the issuance of the emergency heavy rain warning (the evacuation orders (emergency))?" The respondents could choose from the following: "I did not take any particular evacuation behavior"; "I consciously stayed at a safe home"; "I evacuated to the upper level of my house"; "I evacuated to a neighboring building (not a shelter) that I thought was safe"; "I evacuated to an evacuation shelter"; "Other"; and "I do not remember / I do not know." Note that in the analysis, "I do not remember / I do not know" were regarded as missing data.

In addition, after the question about the choice of evacuation behavior at each time point, the respondents were asked to give multiple answers by choosing from 31 items regarding the reasons for evacuation and the reasons why they did not evacuate (see Appendix A).

Table 1. Cross table of evacuation behavior by the levels of housing damages.

	Housing damage	Evacuation behavior: I did not take any particular evacuation behavior	I consciously stayed at a safe home	I evacuated to the upper level of my house	I evacuated to a neighboring building that I thought was safe	I evacuated to an evacuation shelter	Other
Emergency heavy rain warning	Completely destroyed	34%	9%	21%	7%	21%	8%
	Massive half-destroyed	33%	6%	25%	10%	14%	12%
	Half-destroyed	26%	9%	25%	6%	24%	10%
	Partially destroyed	53%	0%	27%	7%	13%	0%
		$\chi^2(15) = 29.71$, $p = .013$					
Evacuation order (emergency)	Completely destroyed	20%	8%	21%	9%	30%	11%
	Massive half-destroyed	21%	7%	24%	10%	21%	16%
	Half-destroyed	21%	8%	24%	8%	30%	9%
	Partially destroyed	13%	13%	38%	13%	13%	13%
		$\chi^2(15) = 17.08$, $p = .314$					

Table 2. Cross table of awareness of hazard maps before the disaster by the levels of housing damages.

Housing damage	Awareness of hazard map: I did not know the word hazard map	I did not know there was one in this area	I had never seen	I have seen	I remembered the contents
Completely destroyed	8%	15%	17%	37%	24%
Massive half-destroyed	6%	16%	20%	42%	16%
Half-destroyed	12%	17%	18%	32%	21%
Partially destroyed	13%	25%	6%	38%	19%
	$\chi^2(12) = 24.25$, $p = .019$				

3. Result

3.1. Evacuation Behavior During the Disaster

In order to examine whether there is a difference in the choice of evacuation behavior at the time of being aware of the emergency heavy rain warning and the evacuation order (emergency) between the damage situations based on the housing damage, a cross-tabulation of the housing damage × the evacuation behavior choice was carried out. According to the cross-tabulation results, at the time of being aware of the emergency heavy rain warning, more than 30% of residents took no action at all (**Table 1**). In particular, among the evacuation behaviors taken by the residents with partially destroyed houses, the percentage of "not taken any particular evacuation behavior" is 53%, the highest of all ($\chi^2(15) = 29.71$, $p = .013$). As for the evacuation behaviors actually carried out, the most frequent choice was evacuation to the upper floor (vertical evacuation), followed by evacuation to the evacuation shelters.

Next, based on the cross-tabulation results, at the time of being aware of the issuance of the evacuation order (emergency) (**Table 1**), 13% of the residents with partially destroyed houses and more than 20% of the other residents took no action at all. However, there was no statistical difference in the choice of evacuation behaviors between the levels of housing damage ($\chi^2(15) = 17.08$, $p = .314$). As in the case of being aware of the emergency heavy rain warning, the most common choice was to evacuate to the upper level (vertical evacuation), followed by evacuation to the evacuation shelters.

The above result indicates that, regardless of housing damage, many of them did not take any evacuation action; although, this percentage decreased as the situation worsened from the emergency heavy rain warning to the evacuation order (emergency).

3.2. Awareness of Hazard Maps Before the Torrential Rain for Each Housing Damage

In order to examine whether there is a difference in the residents' awareness of hazard maps before the disaster between the damage situations based on housing damages, a cross-tabulation of the housing damage × the awareness of hazard maps (**Table 2**) was carried out. According to the results, more than 50% have seen hazard maps. There was a difference in the percentage between the housing damages ($\chi^2(12) = 24.25$, $p = .019$), where this percentage was the highest for the residents with completely destroyed houses at 61%. Although there are differences between the levels of housing damages, many residents had seen hazard maps before the July 2018 heavy rain.

3.3. Residents' Prediction of Flooding Before the Torrential Rain for Each Housing Damage

In order to examine whether there is a difference in the residents' predictions of the flooding before the disaster between the situations of damages based on housing damages, a cross-tabulation of the housing damage × the prediction of the flooding was carried out (**Table 3**). According to the results, more than 60% of the residents

Table 3. Cross table of prediction of flooding before the disaster by the levels of housing damages.

Housing damage	Prediction of flooding before the disaster: I did not think that this area would be damaged by a flood	I did not think we would have floods causing damage	I thought we would have one in the 21st century	I thought we would have one in 10 years or later	I thought we would have one soon
Completely destroyed	17%	62%	6%	6%	10%
Massive half-destroyed	17%	67%	3%	5%	7%
Half-destroyed	14%	63%	4%	8%	11%
Partially destroyed	14%	63%	4%	8%	11%
			$\chi^2(12) = 13.01$, $p = .368$		

Table 4. Cross table of awareness of evacuation shelter before the disaster by the levels of housing damages.

Housing damage	Awareness of evacuation shelter: I did not think I needed to go to an evacuation shelter	I did not know where it was located	I had guessed its whereabouts	I knew it accurately
Completely destroyed	0%	34%	18%	48%
Massive half-destroyed	0%	38%	15%	47%
Half-destroyed	0%	31%	13%	56%
Partially destroyed	0%	35%	18%	47%
		$\chi^2(6) = 7.76$, $p = .256$		

Table 5. Cross table of evacuation planning before the disaster by the levels of housing damages.

Housing damage	Evacuation planning: I did not think that I would need to evacuate	I gave little thought	I had a rough idea	I had made clear plans
Completely destroyed	0%	26%	32%	42%
Massive half-destroyed	0%	32%	34%	34%
Half-destroyed	0%	29%	26%	45%
Partially destroyed	0%	47%	24%	29%
		$\chi^2(6) = 14.03$, $p = .029$		

did not predict the flood. There was no difference in this percentage between the levels of housing damages ($\chi^2(12) = 13.01$, $p = .368$). Thus, although many residents saw the hazard maps (see **Table 2**), it was indicated that less than 30% of residents assumed flood damage.

3.4. Awareness of Evacuation Shelter Before the Torrential Rain for Each Housing Damage

In order to examine whether there is a difference in the residents' awareness of the evacuation shelter during a disaster before the disaster is different between the damage situations based on the housing damage, a cross-tabulation of the housing damage × awareness of the evacuation shelter was carried out (**Table 4**). The result indicates that more than 60% of the residents were aware of the evacuation shelters. There was not much difference in the percentage between the levels of housing damages ($\chi^2(6) = 7.76$, $p = .256$). Thus, many residents were aware of the local evacuation shelters since many of them had lived there for a long time.

3.5. Residents' Evacuation Planning Before the Torrential Rain for Each Housing Damage

In order to examine whether there is a difference in the planning of the residents' evacuation plan during a disaster before the disaster is difference between the situations of the damage based on the housing damage, a cross-tabulation of the housing damage × the evacuation planning during a disaster was carried out (**Table 5**). As a result, more than 50% of the residents had roughly made evacuation plans. The percentage of the residents who had made evacuation plans before the July 2018 heavy rain varies depending on the type of housing damages they had ($\chi^2(6) = 14.03$, $p = .029$). Among all levels of housing damage, 74% of residents with completely destroyed houses had made evacuation plans before the July 2018 heavy rain. This figure is the largest of all. Thus, although there were some differences between the levels of housing damages, many residents had made evacuation plans to some extent before the July 2018 heavy rain.

3.6. Residents' Prediction of Flooding During the Torrential Rain

In order to examine whether there are differences in the prediction of flooding before and after the awareness of the emergency heavy rain warning and before and after the awareness of the evacuation order (emergency) between the situations of damages based on the housing damage, a cross-tabulation of the housing damages at the time of each issuance × the prediction of flooding was

Table 6. Cross table of prediction of flooding during the disaster by the levels of housing damages.

	Housing damage	Prediction of flooding during the disaster: I did not think about anything in particular	I did not think about a disaster	Flooding below the floor level	Flooding above the floor level
Immediately before the emergency heavy rain warning	Completely destroyed	21%	44%	27%	8%
	Massive half-destroyed	20%	53%	22%	4%
	Half-destroyed	22%	53%	18%	8%
	Partially destroyed	33%	56%	6%	6%
		$\chi^2(9) = 24.10$, $p = .004$			
During the emergency heavy rain warning	Completely destroyed	10%	48%	32%	11%
	Massive half-destroyed	10%	61%	23%	6%
	Half-destroyed	9%	57%	19%	15%
	Partially destroyed	7%	73%	13%	7%
		$\chi^2(9) = 39.00$, $p < .001$			
Immediately before the evacuation order (emergency)	Completely destroyed	15%	42%	29%	13%
	Massive half-destroyed	14%	55%	21%	10%
	Half-destroyed	19%	47%	18%	16%
	Partially destroyed	33%	56%	11%	0%
		$\chi^2(9) = 38.99$, $p < .001$			
During the evacuation order (emergency)	Completely destroyed	8%	40%	33%	19%
	Massive half-destroyed	8%	55%	26%	11%
	Half-destroyed	7%	49%	22%	23%
	Partially destroyed	0%	69%	25%	6%
		$\chi^2(9) = 36.71$, $p < .001$			

carried out (**Table 6**). According to the cross-tabulation immediately before the emergency heavy rain warning, more than 60% of the residents did not think that the flooding damage would occur. In particular, 89% of the residents with partially destroyed houses had not thought immediately before the emergency heavy rain warning that flooding damage was going to occur. This figure is the largest percentage ($\chi^2(9) = 24.10$, $p = .004$). As a result of the cross-tabulation at the time of being aware of the emergency heavy rain warning, more than 60% of the residents did not think that flooding would occur. In particular, 80% of the residents with partially destroyed houses did not think during the emergency heavy rain warning that flooding damage was going to occur. This figure is the largest percentage ($\chi^2(9) = 39.00$, $p < .001$). Next, as a result of the cross-tabulation immediately before the issuance of the evacuation order (emergency), more than 60% of the residents did not think that flooding would occur. In particular, 89% of the residents with partially destroyed houses had not thought immediately before the issuance of the evacuation order (emergency) that disaster was going to occur. This figure is the largest percentage ($\chi^2(9) = 38.99$, $p < .001$). According to the cross-tabulation at the time of being aware of the evacuation order (emergency), more than 48% of the residents did not think that flooding would occur. In particular, 69% of the residents with partially destroyed houses did not think during the evacuation order (emergency) that flooding damage was going to occur. This figure is the largest percentage ($\chi^2(9) = 36.71$, $p < .001$).

The above results indicate that even among the residents of the areas having housing damages, a large percentage of the residents with partially destroyed houses thought that flooding damage would not occur although the percentage decreased as the situation worsened from the emergency heavy rain warning to the evacuation order (emergency).

3.7. The Determinants of Residents' Evacuation Behaviors During the Emergency Heavy Rain Warning

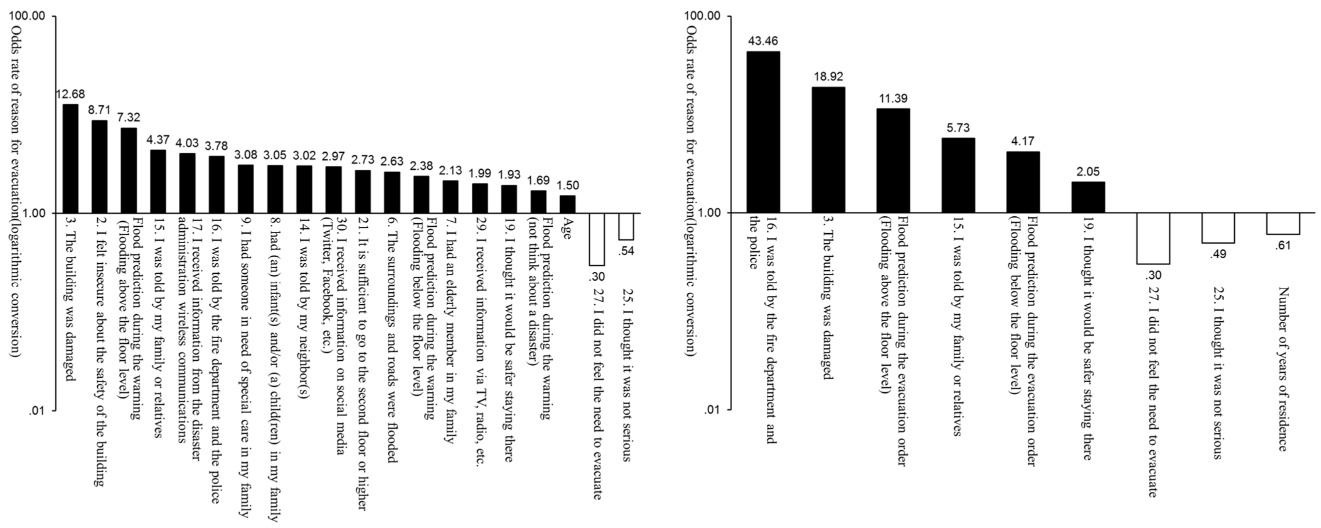
This study examines the residents' characteristics and reasons for evacuation behavior choices at the time of being aware of the emergency heavy rain warning will be discussed. Therefore, an analysis is carried out for $n = 1{,}789$ residents who were at their homes in the affected areas during the emergency heavy rain warning. First, the items of the choice of evacuation behaviors at the time of becoming aware of the emergency heavy rain warning were made into binary dummy variables, where "I did not take any evacuation behavior in particular" was set as 0, and evacuation behaviors such as "I consciously stayed at a safe home," "I evacuated to the upper level of my house," "I evacuated to a neighboring building (not a shelter) that I thought was safe," "I evacuated to an evacuation shelter," and "Other" were set as 1. In the analysis, these variables were used as dependent variables of the evacuation behavior choice. Next, the following were used as dummy variables: gender, level of housing damage, awareness of hazard maps before the disaster, flood prediction before the disaster, awareness of disaster evacuation shelters before the disaster, disaster evacuation planning before the disaster, flood prediction immediately before the emergency heavy rain warning, flood prediction at the time of being aware of the emergency heavy rain warning, and 31 items listed as the reasons of having evacuated or not at the time of being aware of the emergency heavy rain warning. These variables were used as independent variables in the analysis. However, few peo-

Table 7. Results of the Bayesian logistic regression for evacuation behavior during the emergency heavy rain warning.

label	odds rate	mean	se_mean	sd	95%LCI	95%UCI	n_eff	Rhat
Intercept	.454	−.789	.002	.339	−1.455	−.130	23939	1.000
Gender(female)	1.290	.255	.001	.165	−.065	.576	41624	1.000
Age	1.504	.408	.001	.102	.208	.607	26515	1.000
Number of years of residence	.850	−.162	.001	.102	−.364	.038	29255	1.000
Flood prediction (no floods causing damage)	1.081	.078	.001	.190	−.294	.448	23754	1.000
Flood prediction (In the 21st century)	.614	−.488	.002	.385	−1.244	.265	30977	1.000
Flood prediction (In 10 years or later)	1.211	.191	.002	.414	−.595	1.019	32515	1.000
Flood prediction (Soon)	.968	−.033	.002	.367	−.751	.688	29721	1.000
Hazard map (I did not know there was one in this area)	1.087	.083	.002	.288	−.480	.646	15558	1.000
Hazard map (I have never seen one)	1.215	.194	.002	.285	−.363	.754	14375	1.000
Hazard map (I have seen)	.942	−.060	.002	.264	−.576	.458	13554	1.000
Hazard map (I remembered the contents)	.906	−.098	.002	.309	−.705	.512	15542	1.000
Evacuation shelter (Guessed)	.863	−.147	.001	.220	−.576	.292	30750	1.000
Evacuation shelter (I knew it accurately)	.934	−.068	.001	.178	−.419	.280	27356	1.000
Evacuation planning (I had a rough idea)	.970	−.031	.001	.178	−.385	.318	26651	1.000
Evacuation planning (I had made clear plans)	.989	−.011	.001	.211	−.422	.407	26586	1.000
Flood prediction before the warning (not think about a disaster)	1.081	.078	.001	.201	−.315	.474	22010	1.000
Flood prediction before the warning (Flooding below the floor level)	1.362	.309	.002	.267	−.224	.827	21586	1.000
Flood prediction before the warning (Flooding above the floor level)	.558	−.584	.004	.530	−1.631	.472	22935	1.000
Flood prediction during the warning (not think about a disaster)	1.695	.528	.002	.240	.060	1.000	21133	1.000
Flood prediction during the warning (Flooding below the floor level)	2.377	.866	.002	.296	.286	1.453	18419	1.000
Flood prediction during the warning (Flooding above the floor level)	7.316	1.990	.004	.507	1.016	3.011	20920	1.000
Housing damage (Completely destroyed)	.861	−.149	.001	.279	−.697	.390	41720	1.000
Housing damage (Half destroyed)	.760	−.274	.001	.277	−.817	.273	45836	1.000
Housing damage (Partially destroyed)	.506	−.681	.004	.881	−2.395	1.129	43358	1.000
It was raining	1.412	.345	.001	.216	−.074	.769	41680	1.000
I felt insecure about the safety of the building	8.714	2.165	.004	.681	.966	3.641	32380	1.000
The building was damaged	12.675	2.540	.009	1.319	.490	5.671	22119	1.000
It was a one-story house	.390	−.941	.003	.536	−1.992	.119	42509	1.000
Lifelines such as electricity, gas, and water were available	.700	−.356	.001	.271	−.891	.170	34707	1.000
The surroundings and roads were flooded	2.628	.966	.001	.202	.578	1.371	38396	1.000
I had an elderly member in my family	2.133	.757	.002	.341	.105	1.443	39483	1.000
I had (an) infant(s) and/or (a) child(ren) in my family	3.051	1.115	.001	.295	.547	1.706	42242	1.000
I had someone in need of special care in my family	3.084	1.126	.003	.534	.129	2.232	38937	1.000
I had a pet	1.019	.019	.001	.228	−.426	.468	40351	1.000
I thought I could get information and supplies	2.980	1.092	.004	.766	−.333	2.673	37572	1.000
I thought I could get administrative support	2.603	.957	.005	.958	−.710	3.063	31857	1.000
I was told by my neighbor(s)	3.018	1.105	.002	.317	.499	1.741	43936	1.000
I was told by my family or relatives	4.372	1.475	.001	.277	.951	2.022	40563	1.000
I was told by the fire department and the police	3.779	1.330	.004	.716	.055	2.864	38278	1.000
I received information from the disaster administration wireless communications	4.033	1.395	.002	.380	.683	2.175	36545	1.000
It was not raining that much	.623	−.474	.001	.251	−.966	.017	43183	1.000
I thought it would be safer staying there	1.929	.657	.001	.170	.323	.988	41232	1.000
There was no damage to the building	.853	−.159	.001	.258	−.673	.351	38256	1.000
It is sufficient to go to the second floor or higher	2.727	1.003	.001	.174	.666	1.345	40717	1.000
Lifelines such as electricity, gas, and water were not available	.923	−.080	.003	.662	−1.343	1.289	42506	1.000
The surroundings and roads were not flooded	.419	−.869	.001	.220	−1.304	−.436	38664	1.000
I did not have someone in need of special care in my family	1.191	.175	.002	.483	−.757	1.117	45496	1.000
I thought it was not serious	.541	−.614	.001	.171	−.951	−.278	38436	1.000
It was troublesome to evacuate	1.384	.325	.002	.451	−.566	1.198	40484	1.000
I did not feel the need to evacuate	.296	−1.219	.001	.178	−1.573	−.878	38715	1.000
I could not evacuate even though I wanted to	1.141	.132	.002	.339	−.520	.803	39173	1.000
I received information via TV, radio, etc.	1.991	.689	.001	.282	.148	1.252	45145	1.000
I received information on social media (Twitter, Facebook, etc.)	2.970	1.088	.002	.504	.137	2.117	42695	1.000
Other	1.585	.461	.001	.252	−.035	.955	42926	1.000
lp_		−713.265	.065	5.385	−724.868	−703.687	6930	1.000

Note: The interval estimation of coefficients is significant as long as 0 is not included between 95%LCI and 95%UCI.

ple answered, "I wanted by all means to go to a place where people were," which would cause over-dispersion, and thus they were excluded from the analysis. In addition, age and residence variables were used as independent variables of quantitative variables. In order to estimate the presence of evacuation behaviors, a Bayesian logistic regression with Bernoulli distribution was carried out. The analysis was performed in R and the brms package [26]. 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. The analysis results are presented in **Table 7**. In addition, the odds rates of the estimated values based on the posterior distribution of Bayesian estimates are calculated, and the statistically significant variables are presented in **Fig. 1(a)**.



(a) During the emergency heavy warming

(b) During the evacuation order (emergency)

Note: For example, in the leftmost item of **Fig. 1(a)**, the odds ratio of "12.68" given to the item "The building was damaged" means that those who select this item as a reason will be 12.68 times as likely to evacuate compared to those who do not select this. Similarly, "0.30" given to the item "I did not feel the need to evacuate" means that those who select this item as a reason will be 0.30 times as likely to evacuate compared to those who do not select this.

Fig. 1. Odds rates of reasons for evacuation behavior during the emergency heavy rain warning and the evacuation order (emergency).

According to the results, the most powerful reasons that triggered their evacuation behaviors were "The building was damaged" (odds = 12.68, b = 2.54, 95%CI = .490 to 5.671), "I felt insecure about the safety of the building" (odds = 8.71, b = 2.17, 95%CI = .966 to 3.641), and the dummy of the flood prediction at the time of the warning (degree of flooding above the floor level: odds = 7.32, b = 1.99, 95%CI = 1.016 to 3.011). The larger the crisis they perceived was, the higher the rate at which they took evacuation action was. The next influential variable for the people to choosing an evacuation behavior was "I was told by my family or relatives" (odds = 4.37, b = 1.48, 95%CI = .951 to 2.022), "I received information from the disaster administration wireless communications" (odds = 4.03, b = 1.40, 95%CI = .683 to 2.175), and "I was told by the fire department and the police" (odds = 3.78, b = 1.33, 95%CI = .055 to 2.864). The approach from others facilitated the choice of evacuation behaviors. The next influential variables were "I had someone in need of special care in my family" (odds = 3.08, b = 1.13, 95%CI = .129 to 2.232) and "I had (an) infant(s) and/or (a) child(ren) in my family" (odds = 3.05, b = 1.12, 95%CI = .547 to 1.706). The presence of someone with special needs during the disaster had increased the choice of evacuation action. On the other hand, those who chose "I did not feel the need to evacuate" (odds = .30, b = −1.22, 95%CI = −1.573 to −.878) and "I thought it was not serious" (odds = .54, b = −.61, 95%CI = −.951 to −.278) were low in the probability of taking evacuation action. A further characteristic was that the awareness of hazard maps before the July 2018 heavy rain, flood prediction, awareness of evacuation shelters, evacuation plans, and flood prediction immediately before the issuance of the warning had not affected evacuation choice behavior.

3.8. The Determinants of Residents' Evacuation Behavior During the Evacuation Order (Emergency)

This study examines the characteristics and residents' reasons that affected the choice of evacuation behavior at the time of becoming aware of the evacuation order (emergency). Therefore, an analysis is carried out for $n = 438$ residents who were not evacuated and were at their homes during the emergency heavy rain warning. First, similar to the analysis on the awareness of the emergency heavy rain warning, the items of the choice of evacuation behaviors at the time of being aware of the evacuation order (emergency) were made into binary dummy variables. In the analysis, these variables were used as dependent variables of the evacuation behavior choice. The following were used as dummy variables: gender, level of housing damage, awareness of hazard maps before the disaster, flood prediction before the disaster, awareness of disaster evacuation shelters before the disaster, disaster evacuation planning before the disaster, flood prediction immediately before the evacuation order (emergency), flood prediction at the time of being aware of the evacuation order (emergency), and 31 items listed as the reasons of having evacuated or not having evacuated at the time of being aware of the evacuation order (emergency). These variables were used as independent variables in the analysis. However, few people answered "I wanted by all means to go to a place where people were," "It was a one-story house," and "I did not have someone in need of special care in my family," which would cause overdispersion, and thus they were excluded from the analysis.

Table 8. Results of the Bayesian logistic regression for evacuation behavior during the evacuation order.

label	odds rate	mean	se_mean	sd	95%LCI	95%UCI	n_eff	Rhat
Intercept	.169	−1.776	.005	.644	−3.064	−.530	18092	1.000
Gender(female)	.760	−.275	.002	.345	−.963	.394	29441	1.000
Age	1.241	.216	.001	.190	−.154	.594	20197	1.000
Number of years of residence	.606	−.501	.001	.193	−.886	−.124	20042	1.000
Flood prediction (no floods causing damage)	.905	−.100	.003	.361	−.802	.599	19144	1.000
Flood prediction (In the 21st century)	.259	−1.353	.005	.781	−2.934	.144	22508	1.000
Flood prediction (In 10 years or later)	3.383	1.219	.006	1.061	−.798	3.391	26818	1.000
Flood prediction (Soon)	.894	−.112	.005	.771	−1.652	1.389	20933	1.000
Hazard map (I did not know there was one in this area)	1.286	.252	.005	.560	−.819	1.349	10641	1.000
Hazard map (I have never seen one)	.741	−.299	.006	.569	−1.417	.809	10148	1.000
Hazard map (I have seen)	1.114	.108	.005	.524	−.923	1.135	9617	1.000
Hazard map (I remembered the contents)	.619	−.479	.006	.603	−1.677	.699	10949	1.000
Evacuation shelter (Guessed)	.661	−.414	.003	.420	−1.235	.400	22998	1.000
Evacuation shelter (I knew it accurately)	.912	−.093	.002	.328	−.741	.541	23464	1.000
Evacuation planning (I had a rough idea)	1.124	.117	.002	.328	−.543	.753	20720	1.000
Evacuation planning (I had made clear plans)	1.278	.245	.003	.401	−.536	1.022	19619	1.000
Flood prediction before the evacuation order (not think about a disaster)	2.187	.783	.003	.422	−.033	1.613	14721	1.000
Flood prediction before the evacuation order (Flooding below the floor level)	.741	−.300	.005	.562	−1.403	.792	13447	1.000
Flood prediction before the evacuation order (Flooding above the floor level)	.329	−1.112	.007	.956	−3.001	.725	16299	1.000
Flood prediction during the evacuation order (not think about a disaster)	2.588	.951	.004	.492	−.006	1.927	14001	1.000
Flood prediction during the evacuation order (Flooding below the floor level)	4.175	1.429	.005	.602	.278	2.623	12351	1.000
Flood prediction during the evacuation order (Flooding above the floor level)	11.386	2.432	.007	.787	.938	4.053	13134	1.000
Housing damage (Completely destroyed)	.471	−.753	.003	.545	−1.833	.292	29888	1.000
Housing damage (Half destroyed)	.451	−.796	.004	.647	−2.098	.436	29734	1.000
Housing damage (Partially destroyed)	.829	−.188	.012	2.048	−4.471	3.593	30777	1.000
It was raining	1.453	.374	.003	.469	−.541	1.293	32312	1.000
I felt insecure about the safety of the building	4.674	1.542	.007	1.105	−.488	3.857	27722	1.000
The building was damaged	18.918	2.940	.010	1.528	.371	6.432	22525	1.000
Lifelines such as electricity, gas, and water were available	.518	−.657	.003	.530	−1.716	.365	25226	1.000
The surroundings and roads were flooded	1.638	.493	.002	.391	−.262	1.272	30486	1.000
I had an elderly member in my family	2.098	.741	.005	.798	−.785	2.352	26228	1.000
I had (an) infant(s) and/or (a) child(ren) in my family	2.120	.751	.004	.644	−.495	2.043	29026	1.000
I had someone in need of special care in my family	.118	−2.141	.008	1.268	−4.813	.152	24490	1.000
I had a pet	1.681	.519	.002	.399	−.260	1.313	31678	1.000
I thought I could get information and supplies	1.408	.342	.007	1.258	−2.087	2.806	30527	1.000
I thought I could get administrative support	2.272	.821	.008	1.327	−1.676	3.568	30404	1.000
I was told by my neighbor(s)	1.250	.223	.004	.686	−1.127	1.576	30681	1.000
I was told by my family or relatives	5.732	1.746	.004	.591	.643	2.943	27970	1.000
I was told by the fire department and the police	43.458	3.772	.010	1.591	1.134	7.385	23502	1.000
I received information from the disaster administration wireless communications	3.433	1.233	.005	.763	−.196	2.807	28592	1.000
It was not raining that much	.838	−.176	.003	.441	−1.067	.679	31053	1.000
I thought it would be safer staying there	2.048	.717	.002	.321	.096	1.343	28052	1.000
There was no damage to the building	.671	−.399	.003	.424	−1.233	.436	27168	1.000
It is sufficient to go to the second floor or higher	2.765	1.017	.002	.355	.319	1.714	29970	1.000
Lifelines such as electricity, gas, and water were not available	8.676	2.161	.010	1.665	−.854	5.858	28551	1.000
The surroundings and roads were not flooded	.740	−.301	.002	.372	−1.032	.423	27771	1.000
I thought it was not serious	.494	−.705	.002	.327	−1.352	−.068	30837	1.000
It was troublesome to evacuate	.560	−.579	.006	.920	−2.555	1.099	24936	1.000
I did not feel the need to evacuate	.302	−1.197	.002	.341	−1.872	−.541	27808	1.000
I could not evacuate even though I wanted to	.942	−.060	.004	.622	−1.303	1.146	30812	1.000
I received information via TV, radio, etc.	2.897	1.064	.004	.666	−.210	2.431	26032	1.000
I received information on social media (Twitter, Facebook, etc.)	3.786	1.331	.005	.918	−.387	3.198	32252	1.000
Other	2.261	.816	.003	.445	−.042	1.699	28610	1.000
lp_		−256.660	.067	5.565	−268.447	−246.745	6926	1.000

Note: The interval estimation of coefficients is significant as long as 0 is not included between 95%LCI and 95%UCI.

In addition, age and residence variables were used as independent variables of quantitative variables. In order to estimate the presence of evacuation behaviors, a Bayesian logistic regression with Bernoulli distribution was carried out. The analysis was performed in R and the brms package [26]. 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. The analysis results are presented in **Table 8**. In addition, the odds rates of the estimated values based on the posterior distribution of Bayesian estimates are calculated, and the statistically significant variables are presented in **Fig. 1(b)**.

According to the results, the most powerful reason that triggered their evacuation behaviors was "Because I was told by the fire department and the police" (odds = 43.46, b = 3.77, 95%CI = 1.134 to 7.385). The approach from public institutions was an important factor. The next factors that increased the probability of choosing an evacuation behavior were "The building was damaged" (odds = 18.92, b = 2.94, 95%CI = .371 to 6.432), and the dummy of the flood prediction at the time of the issuance of the evacuation order (degree of flooding above the floor level: odds = 11.39, b = 2.43, 95%CI = .938 to 4.053). The larger the crisis they perceived was, the higher the rate at which they took evacuation action was. On the other hand, the evacuation behaviors were inhibited by the influence of the length of residence (odds = .61, b = −.50, 95%CI = −.886 to −.124), in addition to the reasons of "I did not feel the need to evacuate" (odds = .30, b = −1.20, 95%CI = −1.872 to −.541) and "I thought it was not serious" (odds = .49, b = −.71, 95%CI = −1.352 to −.068). The less the residents felt insecure about the disaster and the longer the residents lived, the less they evacuated. In addition, similar to the evacuation behaviors at the time of being aware of the emergency heavy rain warning, the awareness of hazard maps before the July 2018 heavy rain, flood prediction, awareness of evacuation shelters, evacuation plans, and flood prediction immediately before the issuance of the evacuation order had not affected the choice of the evacuation behaviors.

4. Discussion

This study has examined the factors that affect evacuation behaviors by examining the residents' awareness of and the decision-making process before and during the July 2018 heavy rain. Although many residents had seen the hazard maps before the July 2018 heavy rain, the percentage of the residents who predicted flood damage was small. A previous study has indicated that awareness of a hazard map does not affect flood risk perception [11]. It has also been pointed out that knowledge of disasters does not encourage people to take response actions [12]. Since an optimistic bias tends to act in normal times [16], scientific information about disasters does not possibly have a sufficient impact on the formation of people's sense of crisis. In particular, humans tend to fail to adequately respond to objective information such as that provided by hazard maps. For this reason, there is a need for designs that are responsive to the human perceptive mechanism. Expressions by which damage is intuitively grasped are required, such as inserting not only information on the estimated damages but also images of the specific damages to be caused.

Regarding the evacuation behaviors in the July 2018 heavy rain, it was indicated that a certain number of residents did not take any evacuation behavior even in the situation where the houses were damaged. Due to the change from the emergency heavy rain warning to the evacuation order, the number of residents who did not take evacuation behavior was reduced, but residents still did not take action even after receiving each warning. A previous study has indicated that many people did not take safety ensuring actions, even after receiving an earthquake early warning of which the urgency is obvious [15]. In general, it has been pointed out that disaster preventive behaviors are less likely to be taken [16].

Next, regarding the determinants for evacuation behaviors at the time of being aware of the emergency heavy rain warning, those who evacuated were those who were aware of facing a crisis. Previous studies have indicated that affective factors such as fear of disasters trigger countermeasure actions [19, 25]. In addition, approaches from other people such as family members and relatives influenced evacuation behaviors. A previous study has indicated that the approach from close people such as friends and family members facilitates disaster prevention behavior [20]. In addition, people who took care of others with special needs during a disaster, and people with infants and children took evacuation actions. A previous study has also pointed out that the presence of people with special needs during the disaster is a major factor in choosing evacuation behaviors [22].

When the evacuation order was issued, the majority of those who took actual evacuation behaviors was those who were approached by public sectors such as the fire department and the police. It has been indicated that even those who have not taken evacuation action, even though the disaster situation became serious, took evacuation action due to the approach from people around them [9]. Solberg et al. [16] argue that an approach from a social network becomes a strong normative behavior. Those who were aware of facing a crisis also took evacuation action. However, unlike the time of being aware of the emergency heavy rain warning, it was the second factor that affects the choice of evacuation behaviors. A previous study has indicated that the determinants for disaster preventions vary depending on the stage of individual decision-making [25]. There was a difference in the influence of the determinant of the evacuation behaviors between the time of being aware of the emergency heavy rain warning and the time of being aware of the evacuation order. Those who took evacuation behaviors at the time of being aware of the emergency heavy rain warning issued earlier strongly tend to choose behaviors on the basis of their sense of crisis. Those who took evacuation behaviors at the time of the evacuation order issued later did not take action at the time of being aware of the issuance of the emergency heavy rain warning. Therefore, they were encouraged to act at the request of authorities such as public institutions rather than their own sense of crisis. Classical psychology has also pointed out that people are more likely to submit to authorities when faced with situations that are difficult to judge [21].

At the time of the emergency heavy rain warning and at the time of the issuance of the evacuation order, the awareness of hazard maps, flood prediction, awareness of evacuation shelters, evacuation plans, and flood prediction before the issuance of the warning had not affected the choice of the evacuation behaviors. Previous studies have indicated that intuitive System 1 acts in preference to deliberate System 2 in risk determination [6, 7]. Reasonable decisions such as hazard maps and flood prediction are dependent on System 2, and hence they did not affect the choice of evacuation behaviors in the emergency. Instead, evacuation behaviors were chosen as a response of System 1 based on affective decisions such as a sense of crisis. Previous studies have indicated that residents' awareness of hazard maps [11] and flood prediction prior to the occurrence of a disaster [19] do not affect flooding countermeasures. Even the awareness of evacuation shelters and evacuation plans did not affect the choice of evacuation behaviors during the disaster. This point may also be due to an extremely low relevance between the knowledge of disasters and countermeasure actions [12]. The way people react to natural disasters is not rational [13]. Scientific information and knowledge about disasters may have limitations in facilitating people's choice of evacuations behaviors.

This study has some limitations. First, data were collected about five months after the July 2018 heavy rain. It is physically and ethically difficult to conduct a survey immediately after a disaster. There is a certain limitation in interpretation as a judgment of the situation on the day of a disaster. Second, this study targeted residents who have been issued a "victim's certificate of home" during the July 2018 heavy rain. Therefore, it is likely that the survey results are overestimated. In particular, the residents in unaffected areas may have insufficient information and knowledge before the disaster, and their proportion of taking evacuation behaviors during the disaster may be even lower. Although this study has some limitations, it was possible to make the issues on evacuation behaviors clear by examining the determinants for the residents affected by the July 2018 heavy rain to take evacuation behaviors in accordance with the situation change from the emergency heavy rain warning to the issuance of the evacuation order.

5. Conclusions

In the July 2018 heavy rain, the low rate of evacuation behaviors became a problem. On the basis of a survey data of the disaster victim residents in Okayama prefecture, this study has examined the choice of the evacuation behaviors and its determinants at the time of the emergency heavy rain warning and at the time of being aware of the issuance of the evacuation order. As a result, the residents who took evacuation actions in the early stage took actions based on their sense of crisis; those who took actions in the later stage took evacuation behaviors on the basis of an external approach. It is indicated that scientific knowledge and information on disasters are insufficient to trigger evacuation behaviors during a disaster. As pointed out that there is a discrepancy between human judgment and behavior [13], disaster risk communication based on psychological mechanisms is important. The torrential rain disasters are often caused by long-lasting rain. A discrepancy is likely to occur between awareness of hazard maps and disaster prediction in normal times and residents' awareness of the situation at the time of a disaster. During a disaster, communication that arouses an intuitive sense of crisis of System 1 is required in facilitating evacuation behaviors. In the future, based on empirical findings obtained by analyzing the behaviors during a disaster, it is necessary to implement measures to guide people to evacuate following the characteristics of the actual people's decision-making process.

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Appendix A. Reasons for Evacuation Decision

Please tell us the reason(s) for having evacuated, and/or the reason(s) for not having evacuated. Please circle all the applicable below.

1. It was raining
2. I felt insecure about the safety of the building
3. The building was damaged
4. It was a one-story house
5. Lifelines such as electricity, gas, and water were available
6. The surroundings and roads were flooded
7. I had an elderly member in my family
8. I had (an) infant(s) and/or (a) child(ren) in my family
9. I had someone in need of special care in my family
10. I had a pet
11. I wanted by all means to go to a place where people were
12. I thought I could get information and supplies
13. I thought I could get administrative support
14. I was told by my neighbor(s)
15. I was told by my family or relatives
16. I was told by the fire department and the police
17. I received information from the disaster administration wireless communications
18. It was not raining that much
19. I thought it would be safer staying there
20. There was no damage to the building
21. It is sufficient to go to the second floor or higher
22. Lifelines such as electricity, gas, and water were not available
23. The surroundings and roads were not flooded
24. I did not have someone in need of special care in my family
25. I thought it was not serious
26. It was troublesome to evacuate
27. I did not feel the need to evacuate
28. I could not evacuate even though I wanted to
29. I received information via TV, radio, etc.
30. I received information on social media (Twitter, Facebook, etc.)
31. Other

Name:
Shoji Ohtomo

Affiliation:
Professor, Department of Psychology, Faculty of Human Sciences, Konan Women's University

Address:
6-2-23 Morikita-machi, Higashinada-ku, Kobe, Hyogo 658-0001, Japan

Brief Career:
1998-2002 Faculty of Education, Aichi University of Education
2002-2007 Graduate School of Environmental Studies, Nagoya University
2007-2008 Assistant Professor, Graduate School of Information Sciences, Tohoku University

Selected Publications:
• "Public acceptance model for siting a repository of radioactive contaminated waste," J. of Risk Research, doi: 10.1080/13669877.2020.1750457, 2020.
• "The Influences of Residents' Evacuation Patterns in the 2016 Kumamoto Earthquake on Public Risk Perceptions and Trust Toward Authorities," J. Disaster Res., Vol.12, No.6, pp. 1139-1150, 2017.
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Academic Societies & Scientific Organizations:
• Japanese Psychological Association (JPA)
• Society for Risk Analysis, Japan
• European Health Psychology Society (EHPS)

Name:
Reo Kimura

Affiliation:
Professor, School and Graduate School of Human Science and Environment, University of Hyogo

Address:
1-1-12 Shinzaike-honcho, Himeji, Hyogo 670-0092, Japan

Brief Career:
1994-1998 School of Human Sciences, Waseda University
1998-2003 Graduate School of Informatics, Kyoto University
2003-2009 Assistant Professor, Graduate School of Environmental Studies, Nagoya University
2009-2011 Associate Professor, Graduate School of Environmental and Disaster Research, Fuji Tokoha University

Selected Publications:
- "Recovery and Reconstruction Calendar," J. Disaster Res., Vol.2, No.6, pp. 465-474, 2007.
- "Implementation and Operation of a Cloud-Based Participatory Damage Recognition System to Obtain a Common Operational Picture that Supports a Quick Disaster Response," Int. J. for Infonomics, Special Issue Vol.1, Issue 1, pp. 860-866, 2013.
- "Current Status and Issues of Life Recovery Process Three Years After the Great East Japan Earthquake Questionnaire Based on Subjective Estimate of Victims Using Life Recovery Calendar Method," J. Disaster Res., Vol.9, No.sp, pp. 673-689, 2014.
- "Comparison Between the Life Recovery Processes After the Mid-Niigata Earthquake and the Chuetsu-Oki Earthquake – Results of a Random Sampled Social Survey Using the Life Recovery Calendar and GIS-Based Spatiotemporal Analysis," J. Disaster Res., Vol.10, No.2, pp. 196-203, 2015.
- "Issues Facing Voluntary Evacuees from the Fukushima Daiichi Nuclear Power Plant Accident Based on the Collection and Analysis of Cases of Voluntary Evacuation," J. Disaster Res., Vol.10, No.sp, pp. 755-769, 2015.
- "Development of a "Disaster Management Literacy Hub" for Collecting, Creating, and Transmitting Disaster Management Content to Increase Disaster Management Literacy," J. Disaster Res., Vol.12, No.1, pp. 42-56, 2017.
- "A Study on the 2016 Kumamoto Earthquake: Citizen's Evaluation of Earthquake Information and Their Evacuation and Sheltering Behaviors," J. Disaster Res., Vol.12, No.6, pp. 1117-1138, 2017.
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- "Research for Contributing to the Field of Disaster Science: A Review," J. Disaster Res., Vol.15, No.2, pp. 152-164, 2020.

Academic Societies & Scientific Organizations:
- Institute of Social Safety Science (ISSS)
- Japan Society for Natural Disaster Science (JSNDS)
- Japanese Psychological Association (JPA)
- Japanese Society of Social Psychology
- Japan Sociological Society (JSS)
- Seismological Society of Japan (SSJ)
- Japan Society of Civil Engineering (JSCE)

Name:
Yoshiaki Kawata

Affiliation:
Faculty of Social Safety Sciences, Kansai University

Address:
7-1 Hakubai-cho, Takatsuki, Osaka 569-1098, Japan

Brief Career:
1969- Graduated from Department of Civil Engineering, Kyoto University
1976- Obtained Ph.D. from Kyoto University
1981-1993 Associate Professor, Disaster Prevention Research Institute (DPRI), Kyoto University
1981-1982 Research Fellow, University of Washington
1992- Fullbright Senior Research Fellow, Princeton University
1993-2002 Vice President, Natural Hazard Society
1993-2009 Professor, DPRI, Kyoto University
1993, 1994 Best Paper Award, Japan Society of Civil Engineers (JSCE)
2002- Founding Director of Disaster Reduction and Human Renovation Institution
2005-2007 Director, DPRI, Kyoto University
2007-2008 President, Japan Society for Natural Disaster Science (JSNDS)
2007 United Nations Sasakawa Award for Disaster Risk Reduction
2008 Distinguished Services Commendation in the field of disaster management, awarded by the Prime Minister
2009-2011 Dean and Professor, Faculty and Graduate School of Social Safety Science, Kansai University
2009-2012 President, Japan Society for Disaster Information Studies
2010 Social Award of Hyogo Perfecture
2016- Chair Professor and Director, Research Center for Social Safety Science, Kansai University
2016 Achievement Award of JSCE

Selected Publications:
- More than 700 technical papers and 70 books were published in the fields of integrated disaster reduction system of catastrophic disasters including urban disasters and their emergency management.

Academic Societies & Scientific Organizations:
- American Society of Civil Engineers (ASCE)
- International Association for Hydro-Environment Engineering and Research (IAHR)

Name:
Keiko Tamura

Affiliation:
Professor, Risk Management Office, Headquarters for Risk Management, Niigata University

Address:
8050 Ikarashii 2-no-cho, Nishi-ku, Niigata, Niigata 950-2181, Japan

Brief Career:
2004-2006 Researcher, Research Center for Disaster Reduction Systems, Disaster Prevention Research Institute (DPRI), Kyoto University
2006-2009 Associate Professor, Research Center for Natural Hazard & Disaster Recovery, Niigata University
2009- Professor, Risk Management Office/Research Center for Natural Hazard & Disaster Recovery, Niigata University

Selected Publications:
- K. Tamura, I. Rafliana, and P. Kovacs, "Formalizing the Concept of "Build Back Better" Based on the Global Forum on Science and Technology for Disaster Resilience 2017 WG4," J. Disaster Res., Vol.13, No.7, pp. 1187-1192, 2018.
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Academic Societies & Scientific Organizations:
- Institute of Social Safety Science (ISSS)
- Japan Society for Natural Disaster Science (JSNDS)
- Japan Society of Civil Engineers (JSCE)