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Paper No. 435. (quote when citing this article)
Eleventh World Conference on Earthquake Engineering
ISBN: 0 08 042822 3

INHABITANTS' RESPONSES TO AN EARTHQUAKE IN JAPAN

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ABSTRACT

The author, with the objective of minimizing household damage due to earthquakes, conducted a questionnaire survey involving 4,200 citizens in the cities of Choshi, Mito and Iwaki immediately after the 1987 Chibaken-toho-oki earthquake in Japan, so as to investigate the quantitative relationship among human responses, the surounding environment and the strength of the quake. We can understand the behavioral characteristics of inhabitants in case of an earthquake such as initial fire distinguishing capacity or behavioral ability in relation to the strength of shaking experienced by the 1634 respondents.

KEYWORDS

patterns of behavior; behavioral ability; seismic intensities; questionnaire survey; Japan.

INTRODUCTION

There are two serious problems regarding earthquakes in Japan, one is human and material losses during an earthquake caused by fires and the other is injuries occurring indoors due to ground shaking. In the 1923 Kanto earthquake, more than 100,000 people were killed by fires in the Tokyo-Yokohama area. On the basis of data from recent events, injury rates were estimated to be 1% in the urban areas having a seismic intensity VI on the Japanese scale.

To reduce such damage, it is crucial to understand how people react during an earthquake. From such a viewpoint, it has long been desired to grasp how the people react during an earthquake such as patterns of behavior or behavioral ability, etc. in relation to the strength of an earthquake.

In reviewing previous studies, Horiuchi et al. (1975) reported on the relationship between the damage to buildings and the occupant behavior in the 1974 Izu-hanto-oki earthquake. In the 1978 Miyagiken-oki earthquake, Omi et al. (1981) reported on the average patterns of behavior, and Ohashi et al. (1980) wrote a report on the individual characteristics of indoor movement. Ohta et al. (1977) investigated the psychological state and behavior of inhabitants in relation to the seismic intensity on a series of earthquakes in 1970's. Kosaka et al. (1982), Horiguchi et al. (1985), and Mochizuki et al. (1989) also carried out similar surveys concerning several specific types of behavior in three earthquakes during 1980's.

However, those studies were rather rough as regards the measurement of seismic intensity, which was done by a rather large geographical unit, often municipality-to-municipality basis, and small in the volume of data collected. Those also fell short in fully understanding the general

patterns of inhabitant behavior over a wide range of seismic intensities.
The author carried out a questionnaire, in this study, on inhabitants of the affected areas of the 1987 Chibaken-toho-oki earthquake, with a view of evaluating the disaster preventive capabilities of households. This paper is a study to clarify the characteristics of indoor behavior, as well as the behavior of people having already experienced one earthquake and experiencing another.

CONCEPT OF BEHAVIOR

Behavior during the time of shaking will be classified from three veiwpoints: working process, quantitative estimation and qualitative differences.

Action under an earthquake may be divided into the following steps if they are seen as coming from the working process:
Step 1: Consciousness for a some specific behavior first surfacing due to the influence of an earthquake.
Step 2: Moves to the target position of action.
Step 3: Takes a specific action there.

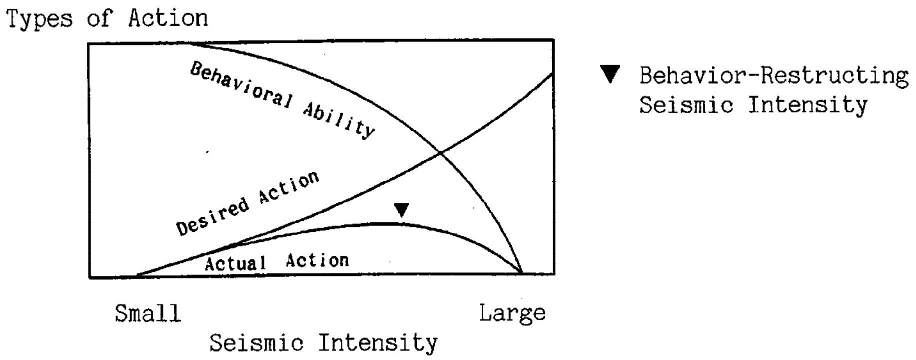

Fig. 1. Relationship between the Degree of Action and Seismic Intensity.

If we understand the people's behavior during an earthquake from the quantitative viewpoint, the types of action taken by the people increase as the shaking becomes stronger. This will be defined as quantity of desired action. On the other hand, because the behavioral ability of people naturally drops as the shaking becomes stronger, the actual quantity of action (types of action carried out) reaches its peak at a certain degree of shaking and then starts decreasing.
The seismic intensity which gives this peak will be defined as the "behavior-restricting seismic intensity" (See Fig. 1).

Various types of behavior will be classified by the qualitative differences into the behavior intended for preventing a deterioration in the surrounding environment (stopping the fire of a gas cooker in use, protecting children, holding furniture, etc.) (positive disaster preventive action) and that intended for one's own safety only (getting under a desk, fleeing outside, etc.) (passive disaster preventive action).

In this paper, the term "fire equipment" can be defined as a gas cooker, a gas fire and an oil stove in use.

SURVEY

The Japan Meteorological Agency reported that the seismic intensity in Choshi City, Mito City and Iwaki City on the 1987 Chibaken-toho-oki Earthquake was V, IV, III, respectively. The author conducted a survey by giving a questionnair to the inhabitants of those three cities, expecting distribution in a wide range of the intensity of the shaking felt by the respondents to the questions. In this survey, 1,400 people were chosen from the voting register of each city and a questionnaire was sent by mail to each person at his/her residence about one month after the occurrence of the earthquake. The questionnaires were sent back by mail with the

1,634(38.9%) actually responding to the survey.

The questions in the questionnaire were intended for estimating the intensity of the shaking and those regarding the human behavior and individual characteristics. The questions intended for estimating the seismic intensity were prepared based on a high-density seismic intensity research method using the questionnaire developed by Ohta et al. (1979).

The seismic intensity, as estimated based on the questionnaire, agrees with the seismic intensity scale of the Japan Meteorological Agency. The seismic intensity of V of the Japan Meteorological Agency is expressed as 5.0. In the following analysis, the seismic degrees from 4.5 to 5.0 by questionnairing are indicated as V^-. Characteristics of behavior according to the seismic intensity will be analyzed using 1,419 samples including 932 persons who were in their homes and 487 persons who were indoors somewhere other than their own houses at the time of the earthquake. The people given the questionnaire were predominantly females with 35.9% being men, 63.4% women and 0.7% unknown. By age group, 8.5% were in their 20s, 15.2% in their 30s, 22.1% 40s, 18.2% 50s, 16.6% 60s and 9.5% 70s and over. The respondents were distributed over a wide range of seismic intensities from I^+ to VI^- with the center being IV^-.

ANALYSIS OF INHABITANTS' BEHAVIOR

Change in Consciousness seen from Their First Response

In this section, we will examine the consciousness of behavior (consciousness of responsive behavior under an emergency) of the action which the subjects tried to take first when they felt the shaking (See Table 1). Therefore, whether they could actually take that action or not is not questioned here. The question concerns the consciousness of the positive disaster preventive action, i.e., action of "fire equipment", "furniture" and "protection". It is worth noting that 30% of the respondents answered that they tried to take some action regarding fire. Answers by choice of free description "I were going to ( )" were represented mainly by such answers as "open the doors or windows", "move to a safe place", "confirm the safety of fire equipment", etc.

Table 1. "What did you try to do first when you felt the shaking? It doesn't matter whether you could do anything or not."

I tried to go to the place of fire equipment.	434 persons	30.4%
I tried to hold furniture.	72	5.1
I tried to protect someone.	95	6.7
I tried to ( ).	192	13.5
I didn't feel the need of doing anything.	359	25.3
I don't remember anything.	126	8.9
No answer.	143	10.1

(N=1421)

Fig. 2 indicates the change in such consciousness according to the seismic intensity. 60% of the respondents, who felt shaking up to the seismic intensity of II^+, answered that they "did not feel the need of doing anything". However, this percentage suddenly drops to no more than 40% of the respondents from the level III^-. Namely, we can understand that people try to estimate the magnitude of the shaking with the conditions of shaking of the house or the movement of objects in the room in the light of the earthquakes they experienced before up to the seismic intensity of II but that they decide to take some concrete action in response to a shaking of any higher intensity. Therefore, the border between the seismic intensity of II^+ and III^- may be interpreted as constituting a threshold level in people's consciousness of responsive action to shaking.

While the consciousness of responsive action to fire equipment is predominant up to the seismic intensity of IV^+, the percentage of consciousness for fire equipment drops and the consciousness for protection of weaker persons and other action relatively increases beyond that level.

The question of Table 1 was followed by questions about the distance to the object of action and the possibility of reaching that point. Those points will be dealt in the latter.

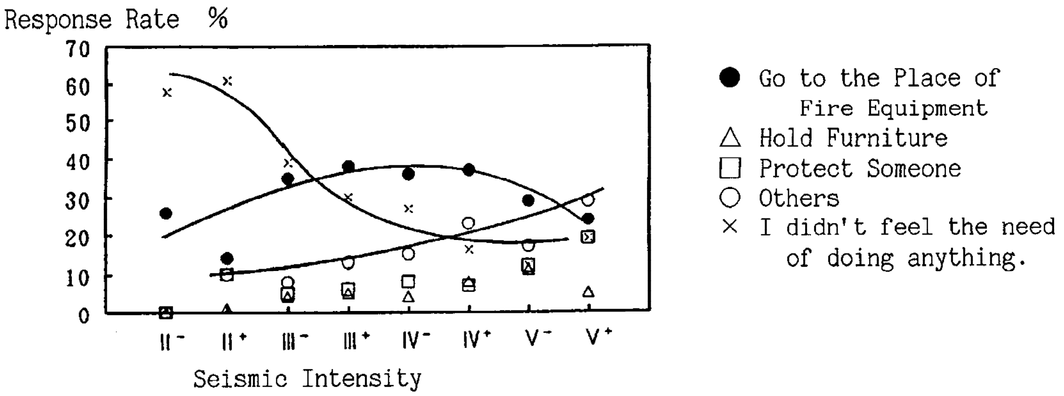

Fig. 2. Change in Consciousness by Seismic Intensity.

Dependence on Seismic Intensity of Behavior

Quantitative Study of Behavior. A question was put to the people if they took the 6 kinds of action (See Table 2) during the shaking. From the said answers to the question by choice of free description on behavior in an emergency, we can see that there is hardly any important or frequently taken action other than those mentioned earlier. Moreover, to understand how many people "could not take any action", the same question provided such choices as "remained quiet because it seemed safer" and "tried but could not move during a strong shaking".

Table 2. "What did you do during the shaking?" Multiple choice questions.

Opened the doors or windows	313 persons	22.0%
Stopped the fire of fire equipment	307	21.6
Protected someone	114	8.0
Held furniture	110	7.7
Fled to outside the house	72	5.1
Got under the desk/table	41	2.9
Took some action else	129	9.1
Remained quiet because it seemed safer	689	48.5
Tried but couldn't move during a strong shaking	156	11.0

(N=1421)

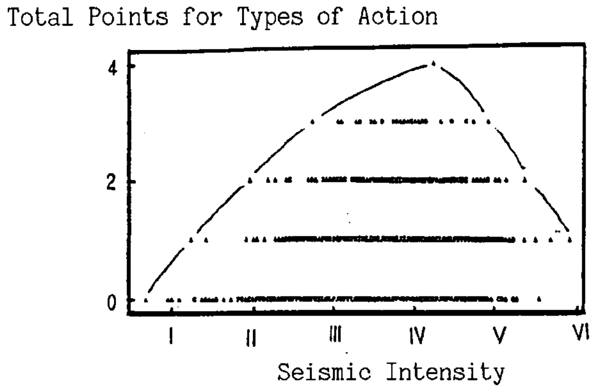

Fig. 3. Quantity of Action by Seismic Intensity.

First of all, let us examine, from the total number of actions taken by individuals, the behavior-restricting seismic intensity of the entire respondents in search for the peak of those actions. To be concrete, one point is given to each action and Fig. 3 indicates the total points of the actions taken by individuals. The envelope of those points indicates the limit of the quantity of action actually taken by the group surveyed and a seismic intensity of approximately IV is estimated to be a behavior-restricting seismic intensity in all the types of action of the group, but this intensity is not so clear.

Secondly, let us determine the behavior-restricting seismic intensity of various kinds of action. For example, if we pay attention to the specific action of "stopped a fire of fire equipment" and divide the number of the inhabitants who took that action by the number of the inhabitants submitted to the same seismic intensity, the quantity of the desired action in Fig. 1 is expressed as the "rate of desired action". In a similar way, the quantity of the action carried out is expressed as the "rate of action carried out".

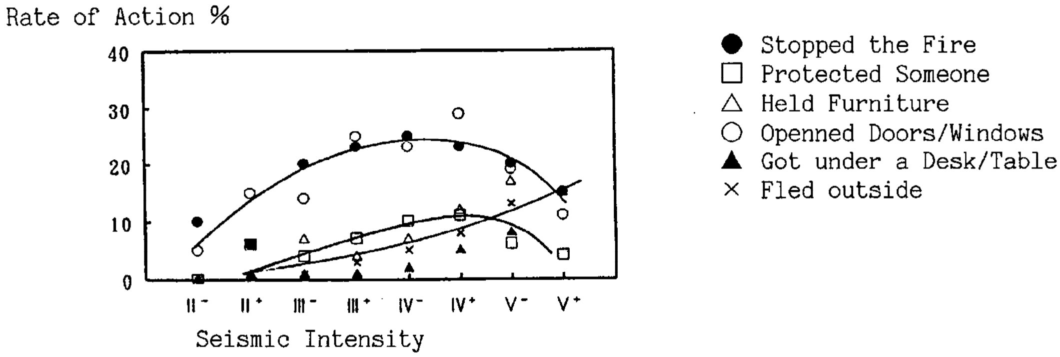

Fig. 4. Rate of Action by Seismic Intensity.

Fig. 4 indicates the progress of the rate of action carried out according to the respective levels of seismic intensity. The respective levels of behavior-restricting seismic intensity are IV^- for "stopped the fire", IV^+ for "openned the door/window", IV^+ for "protected someone" and V^- for "held furniture". From this chart, we can see that specific action appear conspicuously according to the seismic intensity and that the behavior-restricting seismic intensity which represents the peak of the rate of action carried out varies with the type of action.

Qualitative Examination of Behavior. All the kinds of action carried out are arranged in the order of the number of respondents starting from the largest number as can be seen in Table 2. From this table, we can clearly see that "openned the doors/windows" and "stopped the fire of fire equipment" were large in number throughout all the areas surveyed and that positive disaster preventive actions were higher while passive disaster preventive actions were lower in number.

Moreover, by glancing at positive & passive disaster preventive actions by level of seismic intensity in Fig. 4, we can notice that positive disaster preventive action is more conspicuous in areas with comparatively low levels of seismic intensity while the percentage of passive disaster preventive action increases at around a seismic intensity level of about V.

The behavior-restricting seismic intensity for "got under a desk/table" or "fled outside, etc." is unknown from the levels of seismic intensity obtained from this survey. However, as for "fled outside", we can see that this trend increases up to seismic intensity VII by considering the survey results of 41% in an area of seismic intensity VI^- in the 1984 Naganoken-seibu earthquake (Horiguchi et al., 1985) and 71% in an area of seismic intensity VII in the 1948 Fukui earthquake (Mochizuki et al., 1989).

Drop in Behavioral Ability

Knowing the limit of behavioral ability in the midst of shaking is useful for preventing the occurrence of fires or injuries in the event of an earthquake. To grasp if the movement to the target position of action was actually made or not is one of the ways to know the limit of people's behavioral ability at the time of an earthquake.

Dependence on Seismic Intensity of Behavioral Ability. Let us try to grasp the drop in behavioral ability in an earthquake from the progress by level of seismic intensity in the rate of the number of "people who could move to the target position of action" and "people who could not move to the target position of action".

"People who could move" are those who could reach the target position among the respondents who "tried to take some action first when they felt the shaking" mentioned in the former (See Fig. 5). From the chart, we can see that the mobility rate gradually drops as the seismic intensity becomes higher and it suddenly drops from around a seismic intensity of V. The trend of drop in behavioral ability in the chart shows a curved approximation in a logarithmic function. It is, therefore, estimated from this approximate expression that the behavioral ability becomes 0 at seismic intensity of VI.

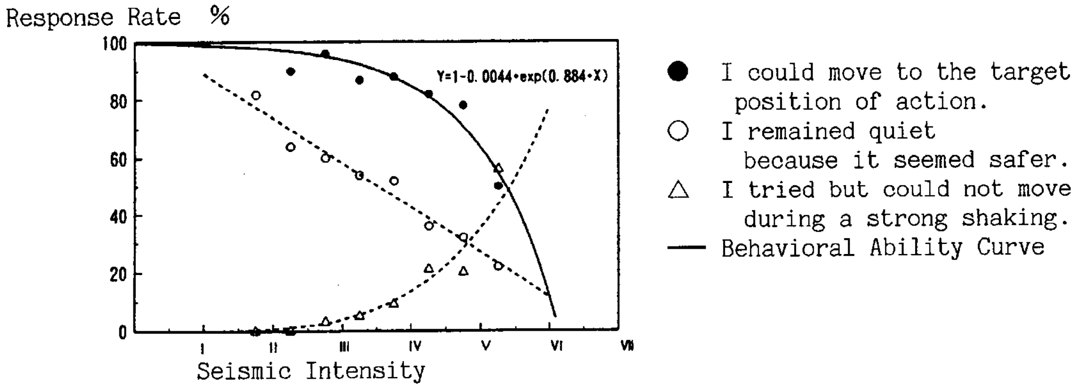

Fig. 5. Drop in Behavioral Ability by Seismic Intensity.

Table 3. Factors of Mobility using a Multivariate Analysis.

Item	Category	Subjects	Category Score
Sex	Male	115	0.23
	Female	216	-0.12
Age range	20s	25	0.71
	30s	63	0.02
	40s	86	0.32
	50s	80	-0.12
	60s	50	-0.47
	70s-	27	-0.49
Physically handicapped	No	318	0.07
	Yes	13	-1.69
Seismic Intensity	III^{-}	38	0.27
	III^{+}	73	-0.11
	IV^{-}	110	0.40
	IV^{+}	68	-0.08
	V^{-}	32	-0.56
	V^{+}	10	-2.27
Distance moved	0 - 2m	91	0.74
	2 - 4m	139	0.16
	4 - 6m	60	-0.36
	6 - 10m	13	-0.86
	10m -	28	-2.06

(N=331)

On the other hand, let us also examine the progress by level of seismic intensity in the rate of the number of respondents who "could not move to the target position of action". Namely, they were people who answered that they "remained quiet because it seemed safer" and "tried but could not move during a strong shaking" as shown in Table 2. The percentages of the respondents who reacted in their respective ways are largely reversed around a seismic intensity of V as the border line, again indicating a sharp decline in the behavioral ability here (See Fig. 5).

Discriminant of Mobility using a Multivariate Analysis. To what individual characteristics the mobility in the room is closely related may be determined by Hayashi's Quantification Theory (Category II) as shown in Table 3.

The table shows a general tendency that the mobility diminishes as the negative value of the category score becomes larger. We can see that people having such individual characteristics as being in their 60s or over, or physically handicapped have a very low behavioral ability during an earthquake and that mobility of people declines remarkably at a seismic intensity of V^- or over. Moreover, the results of the distance they tried to move showed that they could cover a distance of less than 4m from their current position. This indicates that, when using any fire equipment, they should not leave the room in which the equipment is installed even during ordinary times.

Factorial Analysis of Protective Behavior against Fire

Of the 479 respondents who were using some kind of fire equipment at the time of the earthquake (regardless if fire equipment was being used by the respondents themselves or not), 403 people (84%) stopped the fire of fire equipment but the remaining 75 did not.

Dependence on Seismic Intensity of Prostective Action against Fire. By checking the respondents who "stopped the fire of fire equipment" by level of seismic intensity (See Table 4), we notice that this percentage increases in the area in which the seismic intensity passed from II^+ to IV^+. We can understand that the increase in the consciousness of danger leads to the increase of this action as seismic intensity becomes larger.

Table 4. Dependence on seismic intensity regarding the action of "stopping the fire of fire equipment".

	Seismic intensity						
	II^+	III^-	III^+	IV^-	IV^+	V^-	V^+
Stopped the fire	9	44	86	130	84	40	5
(%)	50	76	81	89	99	87	80
Total	18	58	106	146	85	45	10

(N=468)

Table 5. Factors of the ability of "stopping a fire" by a multivariate analysis.

Item	Category	Subjects	Category Score
Seismic Intensity	II^-	4	-0.88
	II^+	10	-0.40
	III^-	45	-0.15
	III^+	73	0.26
	IV^-	98	0.09
	IV^+	55	0.18
	V^-	32	-0.47
	V^+	6	-1.39
Fire equipment user	Respondent	224	0.47
	Another person	99	-1.06
Physically handicapped	No	312	0.02
	Yes	11	-0.84
Intensity of earthquakes experienced in the past	Furniture		
	did not shake at all	90	-0.36
	shook slightly	76	-0.12
	waved considerably	114	0.25
	moved a little	16	-0.33
	moved/tumbled down	27	0.66

(N=323)

However, this percentage seems to drop at an intensity of V⁻ or over. This implies that either it became difficult to take any protective action against fire or some consciousness of danger other than that of fire prevention such as consciousness of danger to one's own body, for example, became conspicuous and priority was given to a protective behavior against it. In any case, we may say that we can expect people to take sufficient protective action against fire only when the seismic intensity is below IV^+ .

Discriminant of the Ability of "Stopping the Fire" using a Multivariate Analysis. Which of the factors that represent concretely individual attributes, change in indoor environment and strength of the quake influence much stronger on the protective action against a fire?

Some influenced stronger factors (Items) picked up from 14 factors are showed using a discriminant analysis (Hayashi's Quantification Theory Category II) (See Table 5). From this result, we can see that the protective action against a fire is strongly influenced by such factors as seismic intensity, user of fire equipment, intensity of earthquakes experienced in the past, presence or not of any physically handicapped in that order. The factors excluded here are sex, age, occupation (employer, employee, unemployed), academic background, location, building type, one's home or the other place, existance of other persons in the same room, existance of fixed heavy furniture, and stuation of body (laying, sitting, standing).

CONCLUSION

The characteristics of human behavior during an earthquake were investigated at a seismic intensity range from II^- to V^+ , and the following conclusions were derived:

1) There exists a threshold intensity between II^+ and III^- , where inhabitants start taking protective action against ground shaking and a deterioration of indoor safety.
2) The intial consciousness of behavior predominantly turns to fire equipment. At a seismic intensity V^- or over, however, this pattern decreases.
3) Up to a seismic intensity of V^- , positive action for disaster prevention, such as rushing to fire equipment, openning doors/windows and protecting children, can be conspicuously seen. At V^+ or over, however, the above pattern is replaced by more passive action, such as getting under a desk or fleeing outside.
4) The behavioral ability suddenly decreases from a seismic intensity V , and this is especially conspicuous for the old and physically handicapped.
5) People should be advised not to leave a room which has fire equipment.
6) From the above conclusions, 3) to 5), it is expected that occupants' protective action against a fire under the shaking to take place up to a seismic intensity IV^+ . At a seismic intensity V or over, it is expected that injuries and fires will occur.

REFERENCES

Horiguchi, T., T. Mochizuki, and K. Kosaka (1985). Study on Human Response in Earthquakes, Part 3: Naganoken-seibu Earthquake of 1984. Comprehensive Urban Studies, 26, 113-116.

Horiuchi, S., A. Sekizawa, Y. Morishita, and H. Mizuno (1975). Field Survey of the Izu-hanto-oki Earthquake of 1974 (No.2), Study on Human Behaviors in the Earthquake. Trans. Archit. Inst. Japan, 234, 51-61.

Kosaka, S., and K. Shiono (1982). An Earthquake and Injuries - The First Step into Prevention of Human Casualties by Means of the Data from the Urakawa-oki Earthquake of 1982; Part 1-. Comprehensive Urban Studies, 17, 41-64.

Mochizuki T., S. Hayasaka, and K. Kosaka (1989). Human Behavior and Casualties in Wooden Houses with Little Ductility. Proc. 9th WCEE , 983-988.

Ohashi, H., and Y. Ohta (1980). Field Survey on Human Response during and after a Large Earthquake Part II , - Collection of Data by Interview Method and Its Tentative Analysis -. J. Seismol. Soc. Japan, 33, 199-214.

Ohta, Y., and H. Ohashi (1979). Field Survey on Human Response during and after a Large Earthquake, Part I , - Collection of Data by Questionnaire Method and Its Tentative Analysis -. J. Seismol. Soc. Japan, 32, 399-413.

Ohta, Y., and S. Omote (1977). An Investigation into Human Psychology and Behavior during an Earthquake. Proc. 6th WCEE, 347-352.

Omi, T., A. Nakamura, M. Shida, and K. Abe (1981). Study on Human Behaviour during Strong Earthquakes in Miyagioki Earthquakes, 1978. Trans. Archit. Inst. Japan, 307, 122-134.