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Correlation between Physiological Index and Psycological Index during Stressful Fire Drills

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ABSTRACT

The purpose of this study is to obtain a better understanding of human behavior in fire. In this study, we measured the physiological indices (sympathetic nerve, parasympathetic nerve) and the psychological index (questionnaires of feelings factors) during fire drills at the Disaster Prevention-Training Center in Hiroshima, Japan. This training center has a unique stressful training program in which drill participants stay overnight. Devices for measuring physiological index were attached to some participants during fire drills. After the fire drills, we conducted questionnaires of feelings factors value on emergency state. We analyzed physiological indices, psychological indices and correlation between physiological indices and psychological indices. As a result of this study, we understood the following results.

1. High sympathetic nerve value and low parasympathetic nerve value were observed during some trainings in which participants have difficulty to forecast next necessary actions.
2. The correlation coefficients among feelings factors were relatively high.
3. The correlation coefficients among sympathetic nerve values, parasympathetic nerve values and feelings factors values were relatively low. Nevertheless, Maximum of parasympathetic nerve values of ratio for average of 24hours tends to be low in the condition of high feelings factors values.

KEYWORDS: questionnaires of psychology, escape, autonomic nerve, sympathetic nerve, parasympathetic nerve

INTRODUCTION

The characteristics of human behavior in emergencies have been well studied in real fires [1], as well as in experiment. To clarify human behavior in fire, experiments with subjects have been conducted. Horiuchi [2] conducted an experiment in a department store to show that the view of the escape route is a key factor for crowd

concentration. Hokugo [3] examined the relation between exit geometry and way finding from the analysis of comparison data with slide experiments. J. D. Sime [4,5] conducted wayfinding experiment in theater type rooms. Hayashi [6] examined the influence of floor surface illumination and the passage width in the T-Junction on the escape route choice. Calligrapher [7,8] examined the influence of wall surface luminance and light source colors on the escape route choice tendency in a model space which simulates escape routes. Hayashi [9] proposed a method for the escape route planing to apply these escape action characteristics.

However, in these experiments, subjects were not given stress as in a fire. These experiments were conducted in normal situations. In the latter half of 1970's, experiments with stress had been started in the medical science and psychology fields. Kuroda [10] classified all body response and behavior of airplane pilots in the stressful condition from sense inputs to actions as information processing. Kugihara [11-13] examined the process of competition and confusion during escape action at bottlenecks.

In addition to these studies, we should examine the influence of the psychological aspects on escape actions in stressful situations. In this context, physiological indices were measured in some studies. Hokugo [14] measured blood pressure changes of subjects when they handled fire escape apparatus. Iida [15] conducted maze experiment and relation between the result of psychological questionnaires and changes of heartbeat and brain waves were analyzed.

However, we didn't think that these indices directly indicate human psychology situation. Because blood pressure and heartbeat are likely affected by body motion.

Recently, autonomous nerve values are used to measure the degree of excitement of human in medical science field. [16] Autonomous nerves are composed of sympathetic nerves and parasympathetic nerves. The sympathetic nerve is said "Nerve of the struggle" [17]. Because it appears when energy is consumed, and the body is turned to an aggressive direction. When value of sympathetic nerve is high, human condition is exited. The parasympathetic nerve is said, "Energy is accumulated", and body is made rest. When value of parasympathetic nerve is high, human condition is steadied.

The sympathetic and parasympathetic nerve values are obtained by R-R interval. Spectrums of time between R-part and R-part in electrocardiogram are analyzed (see Figure 1).

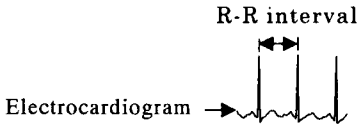


FIGURE 1. R-R interval

We thought that an autonomous nerve value is more suitable than the heartbeat and the blood pressure to understand human psychological state during escape action. Because the autonomous nerve values are less influenced by body motion.

As the method of this study, we measured the sympathetic nerve value and the parasympathetic nerve value during stressful fire drill. We conducted questionnaires on the feelings factors on emergency state. In addition, correlations among sympathetic nerve value, parasympathetic nerve value and the result of questionnaires on feeling factors were analyzed.

EXPERIMENT

In this study, the physiological indices and the psychological indices were measured during disaster prevention.

R-R intervals in electrocardiogram were used as physiology indices. R-R interval measurement device was Active Tracer.(produced by GMS Co., Japan) Before the drill we have asked some drill participants to be experiment subjects. We attached Active Tracers to these subjects.

Date of Experiment, Number of Subjects, Attribute Data of Drill Participants

The experiment was conducted two times in succession for drill participants shown in the Table 1. Each experiment was programmed for two days.

Subjects to be measured R-R intervals were healthy university students (23-25 years old). Because we wanted to obtain excellent R-R interval data. R-R interval data are influenced by aging and women's physiological conditions which are periodically unstable.

Through the questionnaire, attribute data of drill participants were obtained, and ages were twenties-fifties and sexes were male (18 persons) and female (6 persons).

Table 1. shows date of experiment, name of experiment and number of subjects and drill participants.

TABLE 1. Date of experiment, number of subjects and drill participants

Experiment name	Date	Number of subjects and drill participants (persons)	
		R-R interval	Psychological questionnaire
Experiment I	Dec./ 7- 8/1998	4	4
Experiment II	Apr./19-20/1999	10	24

Experiment Place

The experiment took place at the Hiroshima City Disaster Prevention Training Center (Asakita-Ward Hiroshima City, Japan). Figure 2 shows the plan of the fourth floor with staying rooms. This facility is built for overnight training. In addition, the curriculums were mainly provided for fire protection managers in accommodations such as hotels, hospitals and so on. Red lamps are installed on the fourth floor to be presumed as flames. Smoke generator was set up in the corridor and in the guest room. Moreover, monitor cameras are set up on the ceiling of the corridor to monitor drill participants movements.

This Center has a special program. This program includes stressful fire drills.

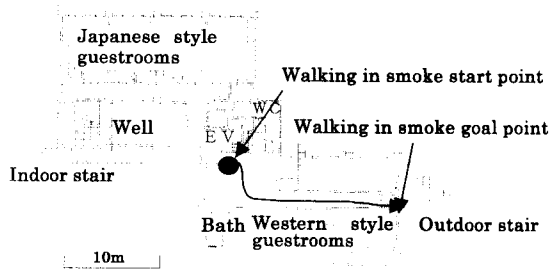


FIGURE 2. Staying floor plan (4th floor)

Accordingly, this special program is suitable for this experiment to analy physiological indices and psychological indices.

Schedule of the Training Program

The training program includes many fire drills. The schedules of trainings were follows. Each total training period was programmed for two days.

Guidance It was conducted in the afternoon of the first day of the training. T outline of the training program was explained in the audiovisual room on the seco floor. The fire department call drill was carried out during the lecture. The lect lasted about one hour.

Walking in smoke It was conducted in evening of the first day. Drill particip walked from the front of EV to the outdoor stairs in the fourth floor (see Figure The smoke was white and non-irritant. The density of smoke was very high. If bring our hands to our face front, we can't see our hands. The image of the flame w produced by sounds of fire and red lamp flashes. The drill participants stooped do and walked along the wall. The walking time was about 30 seconds to walk traini 20meters of corridor.

Training on fire extinguisher operation It was conducted in the evening of the fi day. It was the same training as usual training of fire extinguisher. The dr participants extinguished kerosene under combustion with fire extinguishers. T training lasted about ten minutes.

Integrated training It was conducted at night of the first day. This training was guards and emergency responders. This training includes operation of disas prevention board, fire fighting, and rescuing. One team consisted of three to four dr participants. In this training, one person operated the disaster prevention board the other persons engaged in fire fighting and rescuing dummy hotel guests. T training was conducted for some teams changing, the fire occurrence point etc. T training lasted about 10minutes for one team.

Training at midnight It was conducted in the predawn of the second day. This traini assume that the drill participants were sleeping at the beginning of this drill. The drill participants stayed in a Western-style guestroom and a Japanese-sty guestroom of the fourth floor. The drill participants drank alcohol before they went bed (23:00-2:00). At the start of this drill, the siren and the emergency broadca sounded. (Exp. I 5:57, Exp. II 5:12). The drill participants were informed of t training at midnight but not informed the starting time of this drill. Therefore, so of the drill participants were surprised at the siren and the emergency broadcast.

Virtual fire point was set at third floor of stair-shaft. Fire occurrence point w announced to drill participants through broadcast. And a fire door to outdoor stair w closed before this drill. This fire door was the only fire door left in fourth floor. T drill participants escaped with escape hatch at the in the Western-style guestroo balcony. (see Figure 3) When the escape finished, this training was over.

It was about 10 minutes from the beginning of the drill to the finish of escape.

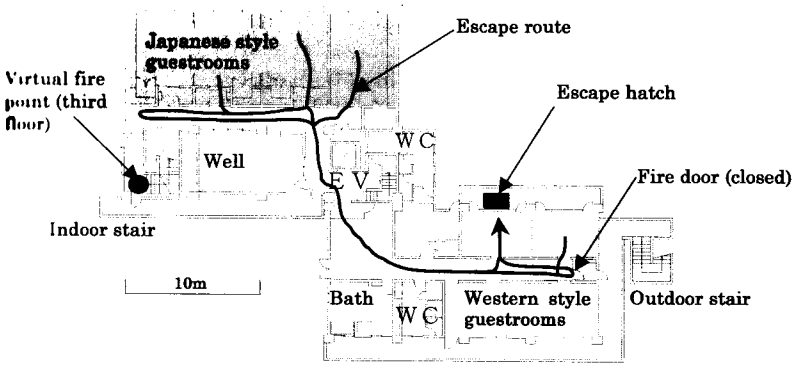


FIGURE 3. Escape route and virtual fire point for training at midnight

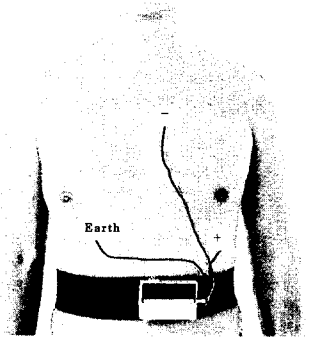
Handling of fire escape apparatus It was conducted in the morning of the second day. The purpose of this training is to have experience in using fire escape apparatus (escape ladder, automatic descending life line, and life chute) from second floor balcony to the ground. This training lasted about 10 minutes.

Measurement and Analysis Method for R-R Intervals

R-R intervals of subjects were measured using Active Tracer AC-301. Attached on the subjects body, this device can be used during disaster prevention training. Active Tracer is small and light enough to wear on the subjects body. (see Photograph 1). This device was attached on the subjects body from few hours before the training until few hours after the training. The attaching time was about 24 hours.

We recorded the actual scenes on site of the fire drill on videotape. Moreover, we checked the motion of subjects with R-R intervals. After the drill, we asked the subjects about their impression and opinion for the drill.

We analyzed sympathetic nerve value and parasympathetic nerve value from R-R interval. R-R interval data have wobble of msec unit. The program MemCalc Ver. 2.5



PHOTOGRAPH 1 Active Tracer on the body of subjects

was used for spectrum analysis. The spectrum analysis was made every one minute for all the time about 24hours from the beginning of measurement to the end of measurement.

Measuring Method of Psychological State During Fire drill

Survey with questionnaire which consist of feelings factors on emergency state with five grades was conducted for every training to each drill participants (see Table2).

TABLE 2. Feelings factors

not excited	–	excited
not anxiety	–	anxiety
not fear	–	fear
not hasty	–	hasty
not tense	–	tense

RESULTS AND DISCUSSIONS

Physiological Index

In this paragraph, physiological indices for each training were examined. The raw data of sympathetic nerve value and parasympathetic nerve value cannot be analyzed. Because this raw data depend on physiological energy of each subject. Then, we calculated the average of these nerve values for 24hours. Because we thought that these average value was average energy for each subject. Moreover, we analyzed ratio of theses average value and raw data of each subject. Then we can understand the inclination in the quality of sympathetic nerve value and parasympathetic nerve value. The maximum, minimum, average and standard deviation (SD=1) for parasympathetic nerve value and sympathetic nerve value ratio for average of 24hours were shown in Figure 4 and 5. Measurement size was 11.

Result of this analysis was as follows.

Guidance The maximum value of the parasympathetic nerve value was higher compared to other trainings. And the maximum of the sympathetic nerve value was the same level as the value of walking in smoke and training of fire extinguisher operation. However, we thought that this program was overall a considerably steady situation.

Walking in smoke The 24hours average was included within the standard deviation SD=1 for maximum of the parasympathetic nerve value, the maximum and the minimum of the sympathetic nerve value. These values were not very difference at 24 hours average.

This result of this training showed that subjects didn't get excited too much. Although the scene was hardly seen in the smoke area during this training, but drill participants understood the site situation before they entered smoke area and the smoke was non-irritant.

Training of fire extinguisher operation The 24hours average was included within the standard deviation SD=1 for the minimum of the parasympathetic nerve value and the maximum of the sympathetic nerve value. This result was the same tendency as for walking in smoke. The drill participants didn't get excited too much.

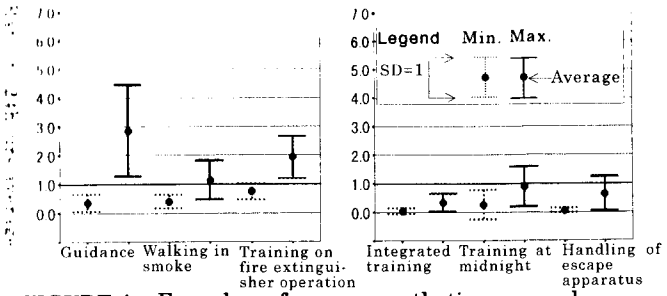


FIGURE 4. Error bar of parasympathetic nerve value

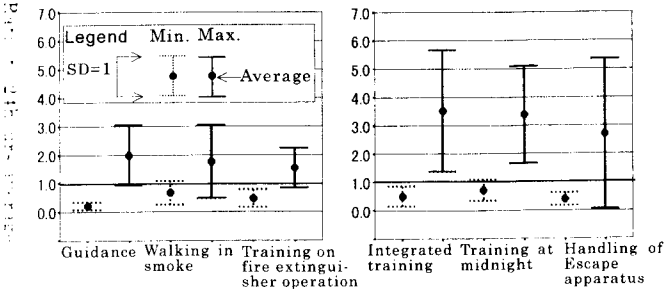


FIGURE 5. Error bar of sympathetic nerve value

Integrated training The minimum and maximum of the parasympathetic nerve value were very low. The maximum of sympathetic nerve value was high. We thought that the fact that the drill participants didn't experience this kind of training was the factor of these results.

Required after the training, the person in charge of rescue told that he didn't hear emergency broadcasting clearly from the person in charge of disaster prevention board. However, other drill participants were able to hear emergency broadcast. We thought that the physiology of the person in charge of rescue changed considerably.

Training at midnight The minimum of the parasympathetic nerve value was low and the maximum of sympathetic nerve value was high.

As the result of this training, drill participants were excited considerably. Because they didn't find the escape route and the training was done in an unexpected situation.

Handling of escape apparatus The maximum of parasympathetic nerve value tendency of this training was similar to that of the integrated training and training at midnight.

Handling of escape equipment was the first experience for the drill participants. Moreover, the drill participants felt that their body was thrown away from the second floor to the first floor.

As the result of these analysis, we understood that sympathetic nerve value was high and parasympathetic nerve value was low when participants have difficulty to forecast next necessary actions.

Psychological Index

Result of Questionnaire for Psychological Factors

For this analysis, maximum feelings factors were chosen to be 5 and minimu feelings factors were chosen to be 1. We handled these numerals as statistical numer Average and standard deviation (SD=1) of the feelings factors were shown in Figure

Responses of the questionnaire were the first time responses of the subjects R-R intervals and other drill participants.

Consequently, "Tense" was higher than other feelings factors at guidance. A feelings factors values were around 4 during the walking in smoke and these valu were high. During the training of fire extinguisher operation, "Tense" and "Excite were somewhat high and other feelings factors values were low. During the handling escape apparatus, all feelings factors values were around 3. During the integrat

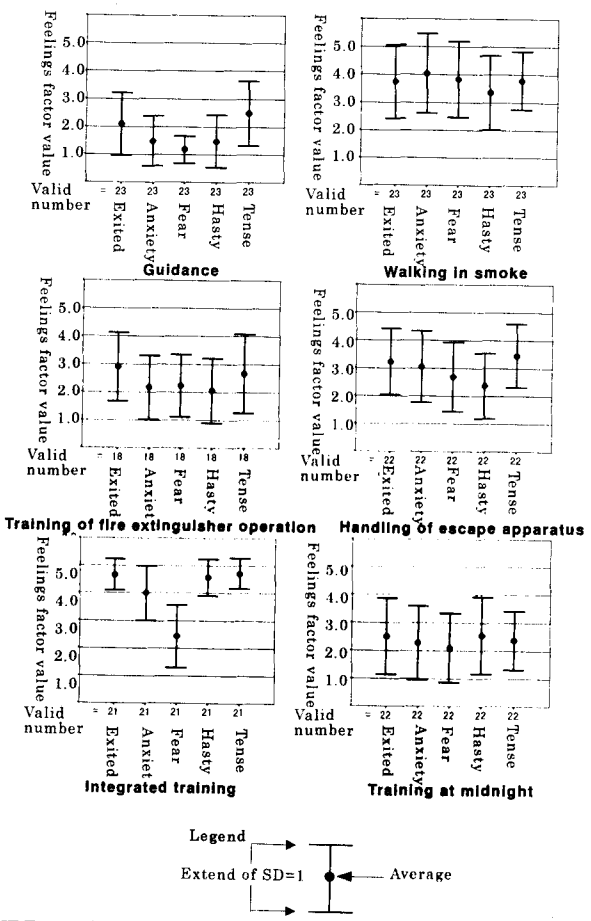


FIGURE 6. Average and standard deviation of questionnaires of psychological for each training

training, feelings factors values were between 4-5 except "Tense". During the training at midnight, feelings factors values were between 2-3.

Correlation Among Feelings Factors

We analyzed the correlation among the feelings factors. The indices of correlation coefficients among the feelings factors were shown in Table3.

The correlation coefficients between "fear" and other feelings factors were relatively low compared to those among other factors.

TABLE 3. Correlation coefficient of between feelings factors (measurement size)

	Excited	Anxiety	Fear	Hasty	Tense
Excited		.776(88)	.589(88)	.686(88)	.819(83)
Anxiety	.776(88)		.738(89)	.803(89)	.789(84)
Fear	.589(88)	.738(89)		.660(89)	.556(84)
Hasty	.686(88)	.803(89)	.660(89)		.770(84)
Tense	.819(83)	.789(84)	.556(84)	.770(84)	

All index of correlation coefficient were 1% level significant (both sides).

Relation Between Physiological Indices and Psychological Indices

We analyzed the correlation coefficient between sympathetic nerve value, parasympathetic nerve value of ratio for average of 24hours and feelings factors. (see Table 4)

The correlation coefficients among sympathetic nerve value, parasympathetic nerve value of ratio for average of 24hours and feelings factors were relatively low. Consequently, we understood that the correlation coefficient between the ratio for average of 24hours of the maximum of parasympathetic nerve value and each feelings factors was the higher than the other correlation coefficient. (half-tone dot meshing in Table4) Nevertheless, Maximum of parasympathetic nerve value of ratio average of 24hours tends to be low in the condition of high feelings factors.

TABLE 4. Correlation coefficient of between each feelings factor and autonomic nerve value

Autonomic nerve value	Data form	Feelings factors				
		Exited	Anxiety	Fear	Hasty	Tense
Sympathetic nerve value	Average	.245*	.175	.142	.245*	.064
	Minimum	.194	.195	.152	.265*	.044
	Maximum	.176	.058	.001	.109	.056
Parasympathetic nerve value	Average	-.305**	-.355**	-.255*	-.295*	-.237
	Minimum	-.154	-.139	-.077	-.125	-.095
	Maximum	-.338**	-.419**	-.377**	-.352**	-.249*

** 1% level significant *5% level significant Measurement size 71

CONCLUSIONS

In this study, we measured the physiological indices (sympathetic nerve parasympathetic nerve) and the psychological index (questionnaires of feeling factors) during fire drills at the Disaster Prevention-Training Center in Hiroshima Japan. We analyzed physiological indices, psychological indices and correlation between physiological indices and psychological indices. As a result of this study, we found that:

1.High sympathetic nerve value and low parasympathetic nerve value were observed during some trainings in which participants have difficulty to forecast next required action.
2.The correlation coefficients among feelings factors were relatively high.
3.The correlation coefficients among sympathetic nerve values, parasympathetic nerve values and feelings factors values were relatively low. Nevertheless, Maximum of parasympathetic nerve value of ratio for average of 24hours tends to be low in the condition of high feelings factors values.

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