

Development of an Experimental Measurement System for Human Error Characteristics and a Pilot Test

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1. Introduction

In a research performed by funding of MSIP(Ministry of Science, ICT and Future Planning), an integrated experimental measurement system to measure various NPP(Nuclear Power Plant) workers' characteristics related to the human error occurrence has been developed. To measure workers' characteristics through experiments and evaluations, a few devices and facilities have been developed or prepared. Through the measurement of workers' characteristics, it is intended to produce basic input data to a human error characteristics database(Eco-DBMS) Fig. 1 shows the experimental measurement system.



Fig. 1 Workers' characteristics measurement and experimental evaluation system.

Meanwhile, in that research, a concept of 'human error characteristics' was suggested. The meaning of human error characteristics is "individual, team, organization, task and environment characteristics which can have an effect on occurrence of or related to the human errors"(Moon). According to the ecological model of human error, individual and team characteristics are the most important factors because they role the subject of final behaviors related to the human error.

Individual and team characteristics related to human error can be measured by various methods. In case of individual, physical characteristics can be measured by

anthropometrical method and some devices. Psychological characteristic or personality, emotion and ability can be measured by questionnaires and evaluation sheets. In addition, physiological characteristics can be evaluated using EEG(Electroencephalogram), ECG(Electrocardiogram), and so on. Team characteristics are measured through observations and questionnaires. In some special cases such as a measurement of team cognitive characteristics for specific situations, the physiological evaluation can be used.

In this study, some items out of individual and team characteristics were partially selected, and a pilot test was performed to measure and evaluate them using the experimental measurement system of human error characteristics. It is one of the processes to produce input data to the Eco-DBMS. And also, through the pilot test, it was tried to take methods to measure and acquire the physiological data, and to develop data format and quantification methods for the database.

2. Experimental Design

2.1. Objective and Scope

In this experiment, it was confirmed that the human error characteristics have relations with human errors. And also, acquiring data for each characteristic for input to the database was performed. Experiments for followings were performed.

- Individual : tension/stress level.
- Environment : noisy and unexpected situation.
- Team : cognitive characteristics of team members on specific situation.

Tension and stress level in the unexpected situation including noise environment were evaluated through the physiological measurement such as a EEG and task performance was assessed. A team cognitive pattern synchronization under same situation was measured by EEG.

2.2. Experimental Task of Experiment A

In the experiment of workers' characteristics measurement in the unexpected situation including noise environment(experiment A), experimental task which consists of 81 steps was designed based on APR-1400 process displays using MS-PowerPoint. The task of experiment A was performed twice with the different

level in different date. Two experimental tries consist of normal and unexpected situation, respectively. The detail of two tries are as following.

- First try of experiment A(A-1, unexpected situation)
 - experimental task : designed task in the above.
 - providing a noise in a specific frequency band at a specific time point during performing task.
 - providing a Public Address related to the HANARO white emergency situation virtually.
 - execution of task for 15 minutes.
 - measurement of physiological data and task performance for 15 minutes.
- Second try of experiment A(A-2, normal situation)
 - experimental task : designed task in the above.
 - execution of task for 15 minutes.
 - measurement of physiological data and task performance for 15 minutes.

2.3. Experimental Task of Experiment B

The experiment B is measuring the cognitive pattern synchronization level of the team members in the specific situation. As a task, a video clip containing people's risky behaviors such as acrobatic and breathtaking actions at high places was provided for about 1-2 minutes. The brain waves of each team member were recorded and then synchronization level was analyzed using the recorded data.

2.4. Measurement Equipment

The equipment utilized in this experiment was a EEG measurement device BPG-S8 which was developed by human factors team of KAERI with an expert company. Fig. 2 shows a configuration of Bios-S8. This equipment can measure brain waves of three persons at the same time and analyze the level of synchronization of them. The analysis result of synchronization level is visualized through a synchronization map which is drawn by multiple lines with thickness and colors that mean correlations between brain positions of each person.



Fig. 2 Configuration of Bios-S8.

2.5. Experimental Subject

Fifteen 9 men and 6 women participated in this experiment. A detail information of subjects is shown in Table 1.

Table 1 Information of experimental subject.

Mean age	Occupation	Gender	Remarks
26.5(±6)	student(11) layperson(4)	men(9) women(6)	no visual and psychological problem

3. Results

3.1. Results of experiment A

3.1.1. Result of EEG analysis

A representative result of EEG analysis of experiment A-1 is shown in Fig. 3. As shown in figure, the portion of theta wave in temporal robe(T7, T8) which is related to the auditory sense increased and theta wave in frontal robe(Fp1, Fp2) which is related to thought and cognition increased at the time point of noise generation. And also, after the public address for emergency situation, the theta waves in frontal and temporal robe a little more increased than after noise generation.

In general, the theta wave is presented in emotional stability or sleeping time, however, it has been reported that theta wave is related to the various states such as concentration and reduction of nervousness in recent researches[1,3]. Accordingly, the above result is concluded that increased theta wave in temporal robe is for reduction of nervousness and tension arisen by displeasing sound, and theta wave increasing in frontal robe is caused by growth of concentration level to complete task fastly in the emergency situation.

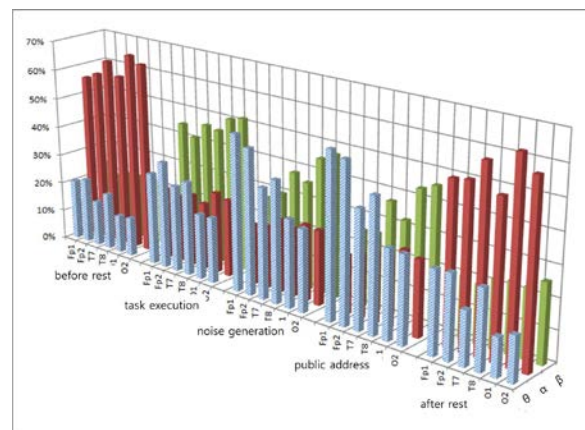


Fig. 3 A result of EEG of experiment A-1.

Fig. 4 is shown a representative result of EEG analysis of experiment A-2. As shown in figure, the result differ from result of experiment A-1. The theta wave in the frontal robe(Fp1, Fp2) increased, but theta waves in other electrode positions decreased overall. It is concluded that there are no external interference and

tension factors such as displeasing sound and emergency situation Whereas, beta wave in occipital robe(O1, O2) obviously increased. It is caused by higher concentration level than A-1 experiment because the task was visual stimuli.

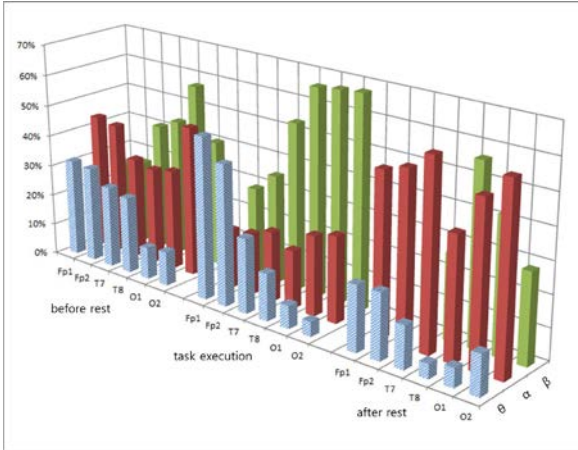


Fig. 4 A result of EEG of experiment A-2.

3.1.2. Result of stress rating

The stress rating of experiment A-1 and A-2 were performed after executions, respectively. The levels of stress which are felt after the experimental executions were rated on the 10 points scale. As shown in Table 2, differences of results of two executions were statistically significant ($p < 0.1$).

Table 2 A result of stress rating of two experiments.

	Mean	SD	SE	DF	t-value	Signif.
Ex A-1	5.840	2.575	.664	14	1.881*	.081
Ex A-2	4.186	2.541	.656	14		

*significant, $\alpha = 0.1$

The Test Anxiety Inventory(TAI)[2] which is modified for the purpose of this experiment was used to measure the levels of tension and stress felt during task performing. In that result, the levels of tension and stress of the experiment A-1 was statistically significantly higher than the experiment A-2($p < 0.05$).

And also, some question items from the questionnaire of Peter Warr[4] were selected to evaluate negative emotions such as 'surprised', 'afraid', and 'unrest' which are can be occurred related to the task execution. As the result, the value of the experiment A-1 was 2.6 and the experiment A-2 was 2.2. The negative emotion level of experiment A-1 was statistically significantly higher than the experiment A-2($p < 0.05$).

3.1.3. Result of task performance

The task performances of two experiments were compared by total executed task numbers out of 81 task numbers during 10 minutes. Table 3 shows a result of

statistical analysis. As shown in table, the task performance of the experiment A-2 was statistically significantly higher than the experiment A-1($p < 0.05$).

Table 3 A result of task performance of two experiments.

	Mean	SD	SE	DF	t-value	Signif.
Ex A-1	45.200	10.871	2.807	14	-2.609*	.021
Ex A-2	55.867	22.077	5.700			

*significant, $\alpha = 0.05$

3.2. Results of experiment B

A movie clip used in this experiment contained people's risky behaviors such as acrobatic and breathtaking actions at high places. Fig.5 visually expresses the synchronization level of brain waves between team members. Red and thicker lines mean higher synchronization level. The synchronization level means that brain wave characteristics in information process which occurred in each brain position of team members are similar. The figure of the upper side shows a high synchronization level among three members, in contrast, the lower side shows a low level synchronization compared to the upper side.

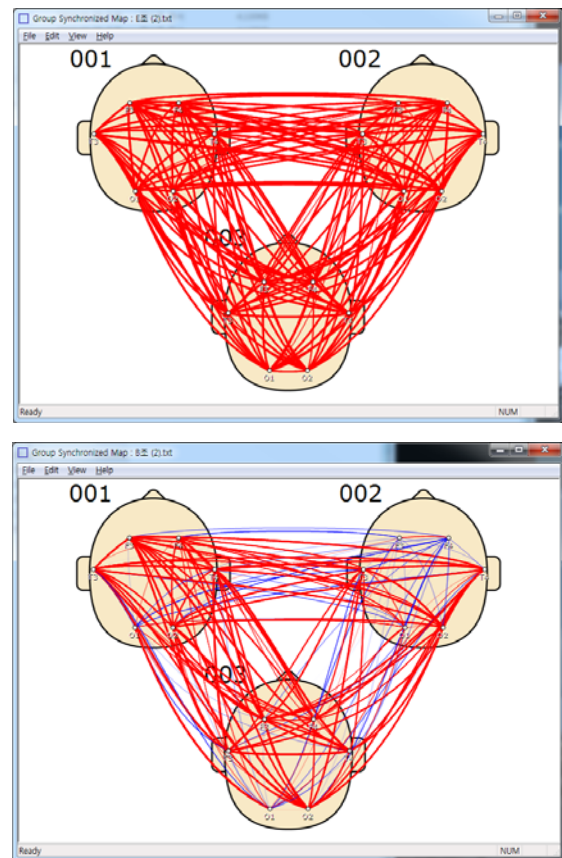


Fig. 5 A result of brain wave synchronization level.

4. Conclusions

In this study, a pilot test to measure the stress and the tension level, and team cognitive characteristics out of human error characteristics was performed using the human error characteristics measurement and experimental evaluation system. In an experiment measuring the stress level, physiological characteristics using EEG was measured in a simulated unexpected situation. As shown in results, although this experiment was pilot, it was validated that relevant results for evaluating human error coping effects of workers' FFD management guidelines and unexpected situation against guidelines can be obtained.

In following researches, additional experiments including other human error characteristics will be conducted. Furthermore, the human error characteristics measurement and experimental evaluation system will be utilized to validate various human error coping solutions such as human factors criteria, design, and guidelines as well as supplement the human error characteristics database.

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