A Study on EEG Analysis in Human Error Potential while using digital device in NPPs

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1. Introduction

Human error potential (HEP) means a possibility of task performance failure based on the final consequence. The HEP of a digital device in nuclear power plants (NPPs) may be caused by perceptual deficiencies of human information processing and miss some operation of the digital device, and so on. There have been many studies to investigate HEP and how to prevent the human error but these mostly focused on probability. We apply a qualitative experimental study on HEP. The purpose of this study is to analyze EEG in HEP during the operation of a digital device in NPPs. We investigate the physiological signal, and evaluate the patterns and specific characteristics of the frequency during the task performance. Within the task process from perception the information to response execution while using a digital device in NPPs, EEG signal shows different pattern. These findings can be utilized to discriminate the HEP in the design of device in NPPs for human errors prevention.

2. Methods

In this study we conducted experiments by measuring the EEG of subjects with the smart phone as a digital device. Before the experiment, HEP is predicted in the study (bold box in table I) by *Error Segment (ES)* and *Interaction Segment (IS)* [2]. They were defined according to exterior physical units and operation options of the digital devices [3]. We found a case of HEP at 'V+' in ES and 'Horizontal mode' in IS (table I). Operators have different intentions about Volume up button (V+) between no option and horizontal mode in IS. However they showed the same response. When the volume up button is in horizontal mode, it has been used to turn down the volume. It is a major cause of confusion to operators by violating the interface design standard about space compatibility. If the volume up button (V+) of ES is in horizontal mode, the volume would be decreased in stages or rapidly. Operators usually are likely to push the left button for decreasing the volume, because the volume up button (V+) is at the left of the device in the horizontal mode.

Five graduate students were not familiar with the device (smart-phone) procedures. Participants were in the 24 ~ 27 age range and their average age was 24.6. It was assumed that subjects were all on the same level of task procedure knowledge. Huang et al. (2007) found that there were no significant differences between experts and beginners therefore; these five students can be regarded as representative participants [1]. They were informed about the experiment's method and randomly completed each trial. While each trial was being completed, there were ten-minute breaks provided to subjects. The tasks were designed based on the results of table I (table II).

Table I: A case of HEP from IS/ES (a part of smart phone)

ES	IS					
Code.	Operation method	Operation situation				
		No option (Vertical mode)	Manner mode	Horizontal mode	Multi task	Lock
P	One Click	Screen on/off				
	Long Click	Pup-up window for option				
V +	One Click	Vol. up by stages	Manner mode cancel and Vol. up by stages	Vol. up by stages (space compatibility violation <u>Operation intention: down</u>	Vol. up by stages	None
	Long Click	Vol. up rapidly	Manner mode cancel and Vol. up rapidly		Vol. up rapidly	None
V -	One Click	Vol. down by stages → manner mode	Vibration	Vol. down by stages (space compatibility violation) <u>Operation intention: up</u>	Vol. down by stages → manner mode	None
	Long Click	Vol. down rapidly → manner mode	Vibration		Vol. down rapidly → manner mode	None
T	Rotation	Move	Move	Move	Move	None
	Click	Selection	Selection	Selection	Selection	None

Table II: Task definition for experiment

Step	ES	IS		Performance Item
		Task 1	Task 2	
1	P	One click **No option**	One click **Horizontal Mode**	Power and screen on
2	M, I, T			Take a picture in the field
3	I, B			Send the message to MCR with short message
4	V			Turn down the volume during step 3

EEGs were recorded by an 8 channel system of the POLYG-I at Laxtha. It was measured by international 10-20 lead standard. Fp1, Fp2, F3, F4, P3, P4, O1, O2 leads were used with Ag/AgCl electrodes. The impedance of each measurement parts was below 10 kΩ on all electrodes. Physiological signals were filtered by a band pass filter and the signal was sampled at 512Hz. The EEG components of the following four frequency bands are obtained delta (0.5~3.5Hz), theta (4~7Hz), alpha (8~12Hz), and beta (13~30Hz). The study conducted EEG experiments and tested error rate and task performance (reaction time) at the same time. The error rate and task performance were confirmed by video recording and observation.

3. Results

This study measured the EEG and tested their error rate and task performance (reaction time) during conducting the experimental tasks. The tasks were pre-designed to include HEP with the digital device. The error rates appeared relatively higher at task 2 than at task 1 and there was a significant difference (*p-value<0.1*). However, the task performance has no correlation with error rates. In this study, we compared the EEG signals between task 1 and 2, and then the frequency pattern analyzed each task in detail. The β frequency usually shows at the strain and stimulant state, α frequency represents the comfort state.

First, the α and β frequency rates during the performing of each task were presented in table III. The β frequency rate was higher in task 2 than task 1. There is a significant difference between task 1 and 2 (*p-value: 0.007*). On the other hand, α rate was lower in task 2. It means that participants mostly have stress in task 2. Secondly, we observed frequency patterns of high error potential in task 2 and compared the spectrum rate. Figure 1 shows each frequency activity from frontal-lobe to occipital-lobe. The left graph is in the non error section and the right graph is in the error potential section. β was higher at the right than at left one and it was, more in especially the occipital-lobe response(fig 1). At the high error potential, high frequency and amplitude appeared and the pattern was unstable (fig 2).

Table III: α and β frequency rate between task 1 and 2

(%)	TASK 1		TASK 2	
	α	β	α	β
Fp1	15.5	15.2	10.3	10
Fp2	14.9	14.6	8.8	8.6
F3	19.5	21.5	26.7	28.8
F4	18.7	20.1	21.2	22.8
P3	24.7	36.1	38.8	37.7
P4	35.3	21.5	21.9	44.5
O1	44	24.7	28.6	47.1
O2	32.1	22.1	23	50
average	25.6	22.0	22.4	**31.2**

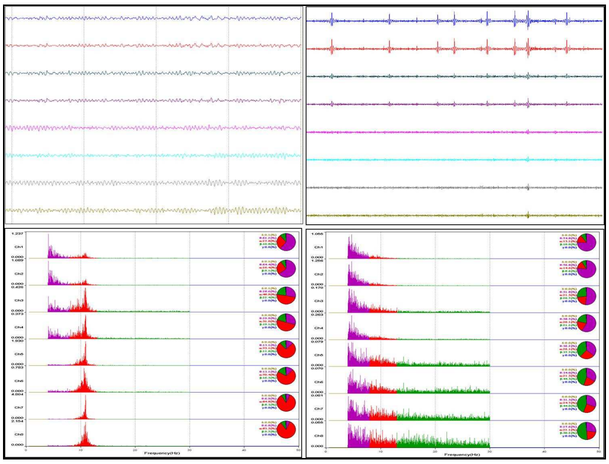

Fig.1. A power spectrum rate from frontal-lobe to occipital-lobe in task 2. The purple graph was θ, the red graph was α, and the green graph was β. As the higher error potential, β increased at occipital lobe.

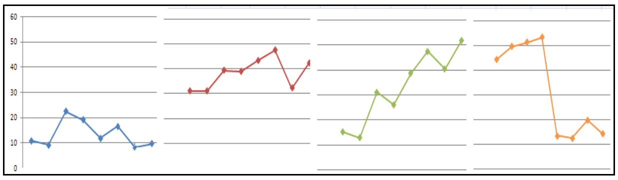

Fig.2. A summary graph described frequency pattern as times goes by in task 2. The blue line (first graph) was showed before task and the red line (second one) was showed while subjects received the visual information and searched the menu of the device. The green one (third) was appeared in HEP. The participant performed tasks even though they didn't know the method exactly just tried until it was right. The last one was getting decreased the frequency when the participants finished the task.

4. Conclusions

It is demanding to discover the HEP of the digital device and the human digital interface to prevent human errors. This study tested the predicted HEP based on *Error Segment* and *Interaction Segment*. Many alarms and user friendly display features in digital devices were not considered adequately to recognize without problems. The study conducted an experiment on an EEG with a digital device (smart-phone) used in NPPs. At the results, frequency showed different pattern during the task performance. In task 2, we recognized error rates increased and the β frequency rate was significantly high. It also showed the different patterns which were unstable and irregular in HEP. If β frequency was kept up continuously during task, work efficiency decreased and caused human error. The EEG response of the user using a digital device is inevitably different according to the task performance. We investigated the EEG pattern to distinguish the HEP and consider the HEP during designing a human digital interface. Further study is required to find out the PSFs from EEG for the design of the digital human interface for NPPs.

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