Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2011

A Human Error Analysis with Physiological Signals during Utilizing Digital Devices

Lee Yong Hee [a], Oh Yeon Ju [a*], Shin Kwang Hyeon [a]
[a] *I&C and Human Factors Division, Korea Atomic Research Institute (KAERI),*
1045 Daeduk-Daero, Yuseong-Gu, Daejeon, 305-353
[*] *Corresponding author: ohyj@kaeri.re.kr*

1. Human Error Studies in Digital Era

The introduction of advanced MCR is accompanied with lots of changes and different forms and features through the virtue of new digital technologies. There are various kinds of digital devices such as flat panel displays, touch screens, and so on. The characteristics of these digital devices give many chances to the interface management, and can be integrated into a compact single workstation in an advanced MCR so that workers can operate the plant with minimum burden during any operating condition. However, these devices may introduce new types of human errors, and thus we need a means to evaluate and prevent such error, especially those related to the digital devices [1]. Human errors have been retrospectively assessed for accident reviews and quantitatively evaluated through HRA for PSA. However, the ergonomic verification and validation is an important process to defend all human error potential in the NPP design. HRA is a crucial part of a PSA, and helps in preparing a countermeasure for design by drawing potential human error items that affect the overall safety of NPPs. Various HRA techniques are available however; they reveal shortages of the HMI design in the digital era.

- HRA techniques depend on PSFs; this means that the scope dealing with human factors is previously limited, and thus all attributes of new digital devices may not be considered in HRA.
- The data used to HRA are not close to the evaluation items. So, human error analysis is not easy to apply to design by several individual experiments and cases.
- The results of HRA are not statistically meaningful because accidents including human errors in NPPs are rare and have been estimated as having an extremely low probability.

2. Task Types and Errors in Advanced MCR

It is important to define the human error mode of task in order to analysis human errors and prevent accidents. There are lots of task types, but this paper investigates them based on tasks with a digital device in advanced MCRs. In particular, this study includes tasks in which operators receive and interpret information, and the response to their task performance. We reviewed the basic characteristics of the tasks required to manipulate the digital devices that have been developed recently and are expected to be introduced into NPPs. The following six types of primitive tasks(Table1) and four error modes(Table2) are classified in terms of cognitive process after a brief pilot study on the users' task behaviors during utilizing digital devices [3, 4].

Table1. Six types of primitive cognitive tasks

Tasks	Description
Type 1	Observation of information on a limited display
Type 2	Decision (inference) of different results from information on the display
Type 3	Memory of data from instrument and indicator
Type 4	Memory of disappeared information on the display
Type 5	Feedback or request of information using H/W and S/W
Type 6	Input of complex information except single information

Table2. Pre-defined error modes and their descriptions

Error Modes	Description
Observation Error	Appears when an operator misses the presented data or takes wrong data on the display.
Decision Error	Appears when an operator gets a wrong idea on the display.
Memory Error	Appears when the operators do not remember the information from the indicator.
Feedback Error	When operators do not react or wrongly feed information back at the request of coworkers.

3. Human Error Analysis by EEG data

The catastrophic consequences of human errors have been occasionally documented in various researches and cases report beginning with the well known accident in NPPs at TMI. And many studies deal with human errors by developing techniques with cognitive model and conducting several experiments: cognitive type classification, following-up of personal propensity to cause errors, workload analysis through task reaction time etc. Norman described the psychological failings of human error in everyday life, and Reason described slips, mistakes, and violations as well as their cognitive constructs that underlie the commission of the types of errors. There need a way to ensure the validity by getting more objective and quantitative data. Recently Fedota and Parasuraman argued traditional ergonomics approaches especially error related negativity (ERN) in EEG to understanding many aspects of human task performance and errors in neuro-ergonomics [2]. We conducted a series of experiments by measuring the physiological signals such as EEG, ECG, and GSR during the given experimental tasks. We analyzed many plausible measures to indicate the human error potential which constructs an erroneous cognitive state when utilizing the digital devices in advance MCR. Figure 1 shows the defined error modes and experiment tasks from the types of tasks classified in advanced MCRs with digital devices. Following table 3 shows four experimental tasks designed and figure 2 shows the designed display screens for the tasks.

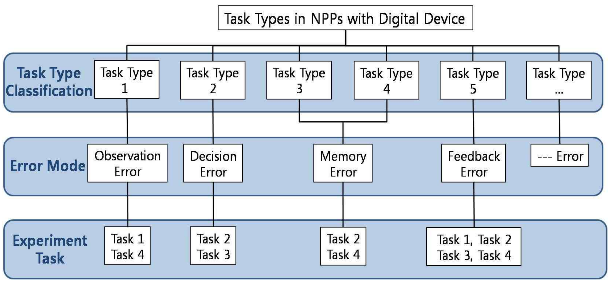

Fig.1. Error modes and experimental tasks for classified tasks

Table 3. Four tasks designed for the human error experiment

Experiment Tasks	Description and the error related
Exp-Task 1	To find an array of invalid characters in a given paragraph. Subjects may search for an erroneous number of data or do not respond.
Exp-Task 2	To search an omitted figure of the numbers listed in the calendar section. Subjects may not find the data or obtain a wrong figure.
Exp-Task 3	To perform an operation. Subjects may calculate incorrectly or do not interpret properly the presented information.
Exp-Task 4	To remember the requested data of rows in the matrix. Subjects may remember incorrectly or not response upon demand.

Fig.2. Experimental screens for four experiment tasks

The EEG analysis is an important measure to capture the mental state of human during the decision making and information processing. Traditionally EEG is observed dominant in active physical and mental action level. Especially beta frequency (13~30Hz) shows strain and apprehension state from visual and auditory stimulus, thus the occurrence of a human error is highly probable. And then alpha (8~12Hz) shows the relax state. Thus we detected alpha and beta frequencies in EEG data and analyzed the frequency rate and pattern among the experiment tasks and error modes.

4. Results

Physiological signals of twenty subjects were measured while conducting four types of experimental tasks. We investigated the EEG data by the absolute frequency rate analysis and the frequency pattern analysis. Figure 3 showed a result of absolute frequency rate analysis by each task. The beta frequency of the right response was significantly lower than wrong and no responses (*p-value<0.1*) in all error mode (observation, decision, memory, feedback). Especially, the beta rates in the wrong response were significantly higher than them in the no response (*p-value<0.05*). Most operators felt anxious extremely when they missed the information displayed and got several wrong data without any feedback from the request. Figure 4 presented the results of relative frequency pattern analysis from visual stimuli to subject's response. These graphs shows the difference not only between errors (wrong and no response) and non-error (right response), but also between the error types. We confirmed that the cognitive process became unstable when the subjects found out by themselves the error in the error section.

Fig.3. A result of absolute frequency rate analysis

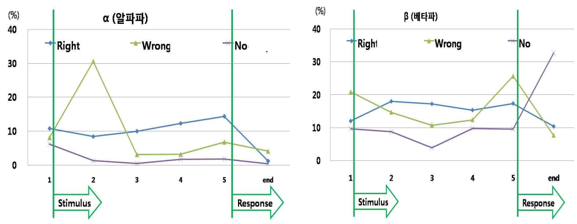

Fig. 4. Results of relative frequency pattern analysis

5. Conclusions

This study shows the possibility to capture human error potentials based on the analysis of physiological data of users while conducting several selected tasks with digital devices. It may be applied to the design review of HMI to be introduced to an advanced digital MCR in NPPs. We classified the six cognitive tasks during utilizing digital devices and defined four error modes in terms of cognitive processes. We found out that the human error potential by the EEG measures becomes significantly high during the task especially in error modes. The suggested error modes and EEG measure can be applied to predict the human errors of the tasks related to the digital devices to be introduced to NPPs.

REFERENCES

[1] Jang T.I., Lee Y.H., Lim H.K., A Modification of Human Error Analysis Technique for Designing MMI in MPPs, J. Ergonomics Society of Korea, Vol.22, 1, pp.31-42, 2003.
[2] Fedota J.R., Parasuraman, R., Neuroergonomics and human error, Theoretical Issue in Ergonomics Science, Vol. 11, No. 5, pp.402-421, 2010
[3] Oh Y.J., Lee Y.H., A Study on EEG Signal and Human Error Potential while using a Digital Device in NPPs, Proc. Spring Conf. of Korean Nuclear Society, 2011
[4] Oh Y.J., Lee Y.H., A Study on the Operator's Erroneous Responses to the New Human Interface of a Digital Device to be introduced to NPPs, Proc. Conf. HCI International 2011, USA, 2011