A New Human-Machine Interfaces of Computer-based Procedure System to Reduce the Team Errors in Nuclear Power Plants

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1. Introduction

In nuclear industry, human errors have been recently highlighted again after the recognition of the importance of the personal aspect as well as the system aspect in Fukushima accident [1]. The system side of the human errors still reveals the rooms to improve further not only the working environment, but also the management such as policy, personnel organization, reward and punishment, and education and training system, etc. The personal aspect of human errors has been mainly overcome by virtue of the education and training. However, in the system aspect, the education and training system needs to be reconsidered for more effective reduction of human errors affected from various systems hazards. Traditionally the education and training systems are mainly not focused on team skills such as communication, situational awareness, and coordination, etc. but individual knowledge, skill, and attitude. However, the team factor is one of the crucial issues to reduce the human errors in most industries [2].

In this study, we identify the emerging types of team errors, especially, in digitalized control room of nuclear power plants such as the APR-1400 main control room of Korea. Most works in nuclear industry are to be performed by a team of more than two persons. Even though the individual errors can be detected and recovered by the qualified others and/or the well trained team, it is rather seldom that the errors by team could be easily detected and properly recovered by the team itself. Note that the team is defined as two or more people who are appropriately interacting with each other, and the team is a dependent aggregate, which accomplishes a valuable goal [3]. Team error is one of the typical organizational errors that may occur during performing operations in nuclear power plants. In other words, team error is defined as human error made in team process [3]. Organizational errors sometimes increase the likelihood of operator errors through the active failure pathway and, at the same time, enhance the possibility of adverse outcomes through defensive weaknesses [4].

We incorporate the crew resource management as a representative approach to deal with the team factors of the human errors. We suggest a set of crew resource management training procedures under the unsafe environments where human errors can have devastating effects. Additionally, contingency guides and supporting tools are proposed for recovering the team errors in control room of nuclear power plants.

In general, there are three perspectives for human errors; individual, team, and organizational perspectives. According to the each human error perspective, different countermeasures are needed for reducing human errors because different factors accordance with those perspectives affect human errors as Fig. 1 [5]. So that the team errors should be considered with team perspective such as team decision-making, leadership & followership, shared situational awareness, shared mental model, team communication, team coordination, team spirit, etc.

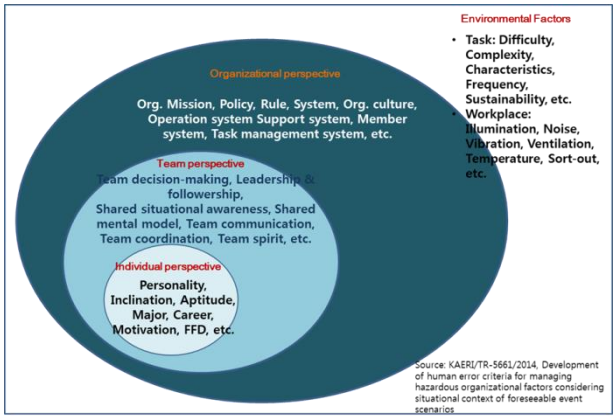

Fig. 1. Three perspectives for human errors

In the team perspective, team performance and effectiveness are the main topics to improve productivity and safety. However, team error has been dealt with one of the causes or performance shaping factors. Team error is recognized as a typical type of human errors also. Team performance is influenced by factors occurring not only at the team level but also at levels above and below such as culture, climate, individual performance, which can make it difficult to determine the root cause of a team failure [6]. Also, errors within teams can originate and manifest at both the individual and collective levels of analysis [7]. Bell and Kozlowski studied about the moderating influence of task interdependence on the relationship between individual and team error.

In nuclear industry, team error is a challengeable topic because most of human errors have been dealt as an individual failure or organizational failure. Recently as digitalized techniques are adopted in control room of

nuclear power plants, new digital interfaces make new concerns relevance with team communication, shared situational awareness, etc. The new team error issues related with digital control room are following:

- Shared situational awareness among team members - Individual situational awareness could be better. However, shared situational awareness could be worse;
- Sensitive team stability - Fluctuating change in a team could make problems such as poor leadership, declined team learning;
- Shared mental model - Different mental models could be coexisting in a team due to multi-generations;
- Team communication - Low frequent communication among team members owing to difficult of the 'Face to Face' communication and change of operational concept;
- Shared task procedures - Team members could perceive different task procedure each other in case of using computer-based procedures;
- Leader's mental workload - Leader should obtain much more information in his or her workstation in order to confirm the plant situations, which are reported by team members.

To cope with the current issues, we determined the following strategic countermeasures through experts' brain storming;

- Shared situational awareness among team members: A group-view display is determined as a vital coping tool. One of the strategic countermeasures is to provide common cues in a group-view display to share the situational awareness among operators. For example, providing a temporal pop-up in the group-view display whenever someone controls a component or system or providing a temporal mark-up function to leader in the group-view display using such as air writing technology or laser pointing marking technology are the representative countermeasures.
- Sensitive team stability: A crew resource management (CRM) training program is determined as a vital coping tool. Providing a CRM training program is to enhance adaptation ability against team instability such as a team error management program, team-customized training program, or leadership paired followership training program.
- Shared mental model: A crew resource management (CRM) training program is determined as a vital coping tool. Providing a CRM training program is to enhance shared mental model and shared understanding such as making a shared space through team seminar and dialogue and role playing. Also, providing a joint CRM training program is to enhance each understanding.
- Team communication: A computer-based procedure system is determined as a vital coping tool. Providing communication steps in the computer-based procedure system is to facilitate team members' communication via essential steps to communicate with each other or confirming function into the communication steps. Also, providing a supervision display to team leader using web-camera is to make more complete communication among team members.
- Shared task procedures: A computer-based procedure system is determined as a vital coping tool. Providing confirmed or be active information in a computer-based procedure system is one of the countermeasures.
- Leader's mental workload: To reduce the leader's mental workload in the digital control room, a new staffing is necessary. Providing vice-leader to share the leader's mental workload is a vital resolution. A new vice-leader as a safety technical assistant is one of the countermeasures. Also, providing a supporting system to help critical decision-makings is one of the other resolutions.

As mentioned above, we proposed countermeasures against team errors in terms of human-machine interfaces (HMI). Especially a computer-based procedure system is dealt with important digital interfaces in terms of team communication and shared task procedures in main control room of nuclear power plants. This is because a computer-based procedure system has been chosen a representative digital interface in the advanced control room. Also the computer-based procedure system is deeply related with team activities to operate nuclear power plants too.

2. Methods and Results

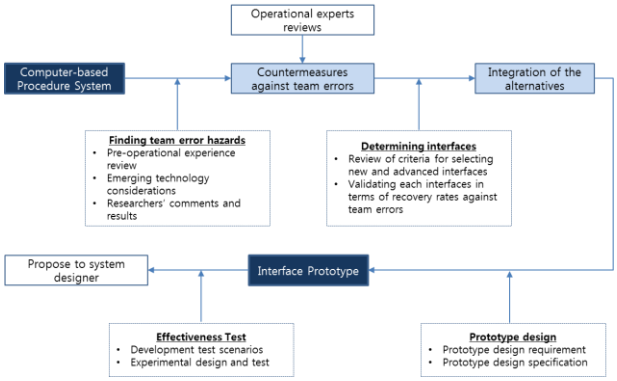

Figure 2. Development Process

The process for developing a revised computer-based procedure system is described in Figure 2. We reviewed pre-operational experience through interviewing current operators who are working for the KHNP in Kori site. Also we reviewed literatures

relevant to emerging technology in advanced control room. To find foreseeable team errors in a condition of using a computer-based procedure system in main control room, we analyzed team error mechanism with operational experts using the team error process model [3] of Figure 3.

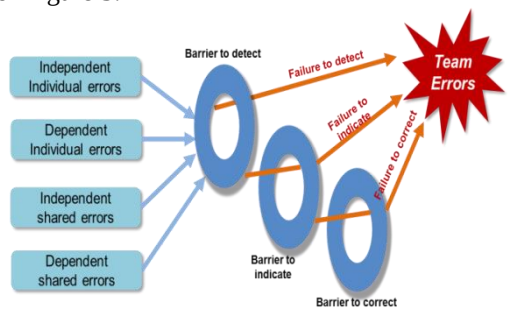

Figure 3. Team error process model by Sasou & Reason

We also analyzed feasible scenarios related with team errors in a condition of using a computer-based procedure system. The analysis was performed based on the team error process model as an example of Figure 4.

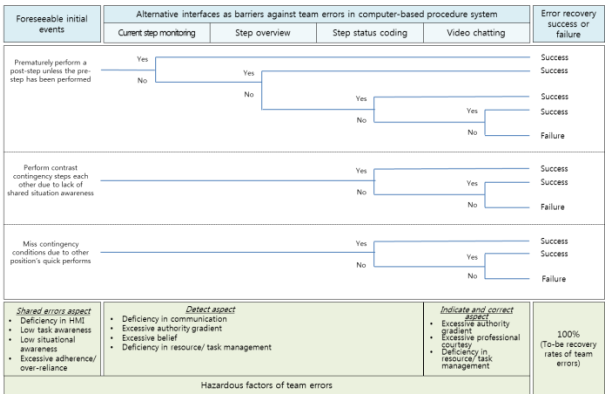

Figure 4. Scenario analysis of team error recovery success or failure

As results, we proposed following four types of new interfaces (refer Figure 5) to reduce team errors in case of using computer-based procedure system.

- Current step monitoring: In case of synchronized condition, each operator can monitor current steps of others
- Step overview: Operators can confirm the step overview of the current procedure
- Step status coding: Step status provided by color coding
- Video chatting: Each operator can chat each other using video chatting function

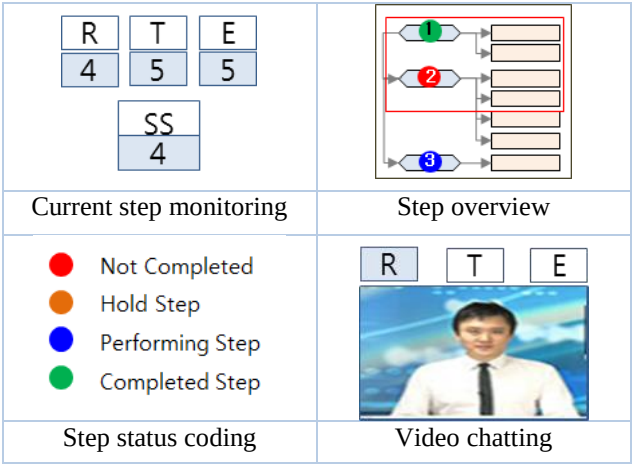

Figure 5. New interfaces of computer-based procedure system

3. Conclusions

We are on the way to develop alternative interfaces against team error in a condition of using a computer-based procedure system in a digitalized main control room. The computer-based procedure system is a representative feature of digitalized control room. In this study, we will propose new interfaces of computer-based procedure system to reduce feasible team errors. We are on the way of effectiveness test to validate whether the new interface can reduce team errors during operating with a computer-based procedure system in a digitalized control room. After validating the effectiveness through the experimental way, we will propose a revised computer-based procedure system. Of cause, the adoption and application are the other business.

Acknowledgements

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIP). The project number is 2012M2A8A-4004256.

REFERENCES

[1] IAEA, Human and organizational factors in nuclear safety in the light of the accident at the Fukushima Daiichi nuclear power plant, 2014.
[2] Salas, E., Dickenson, T.L., Converse, S., Tanenbaum, S.I., Toward an understanding of team performance and training, In R.W. Swezey, E. Salas(Eds.), Teams: Their training and performance, pp.3-29, Norwood: Ablex, 1992.
[3] Sasou, K. and Reason, J., Team errors: definition and taxonomy, Reliability Engineering and System Safety, Vol. 65, pp.1-9, 1999.
[4] Reason, J., The human contribution: Unsafe acts, accident and heroic recoveries, Surrey, UK: Ashgate, 2008
[5] Kim S. K., Luo Meiling, Lee Y. H. (2014), An Analysis on Human Error Mechanism using System Dynamics:

Organizational Factors Aspect, KAERI/TR-5661, Korea Atomic Energy Research Institute.
[6] Rosen M. A., Salas E., Wilson K. A., King H. B., Salisbury, M., Augenstein J. S., et al., (2008), Measuring team performance in simulation-based training: Adopting best practices for healthcare. Simulation and Healthcare, Vol. 3, pp 33-41.
[7] Bell B. S., Kozlowski S. W. J. (2011), Collective failure: the emergence, consequences, and management of errors in teams, In Hofmann, D. A. and Frese M., Error in organizations.