Comparative Study of Communication Error between Conventional and Digital MCR Operators in NPPs

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1. Introduction

Large process control systems including nuclear power plant (NPP), railway, and aviation systems are operated by human operators as part of a system. To operate such system efficiently and safely, proper interaction and collaboration between system components are very important. Especially, for human operators, communication is necessary to share information between individuals, coordinate actions on the system, pool expert resources to solve problems, and as a mean of validating system knowledge [1]. In this regard, the appropriate communication is directly related to the efficient and safe system operation, and inappropriate communication is one of the main causes of the accidents in various industries since inappropriate communications can cause a lack of necessary information exchange between operators and lead to serious consequences in large process systems such as nuclear power plants [2]. According to the study conducted by Y. Hirotsu in 2001, about 25 percents of human error caused incidents in NPPs were related to communication issues [3]. Also, other studies were reported that 85 percents of human error caused incidents in aviation industry and 92 percents in railway industry were related to communication problems [4][5].

Accordingly, the importance of the efforts for reducing inappropriate communications has been emphasized in order to enhance the safety of pre-described systems. With the enhancement of digital technologies, the main control rooms (MCRs) in existing NPPs and newly constructing NPPs were digitalized with the implementation of computerized procedure system (CPS), large display panel (LDP), and many kinds of new features. Many studies were conducted to identify the influences of digitalized MCRs on human errors. However, it is not clear that digitalized MCRs really feasible regarding the frequency of inappropriate communication occurrence compare to conventional MCRs, although inappropriate communication can cause serious problems for nuclear safety.

In this study, the communication errors in conventional MCRs and digital MCRs were investigated and compared. In section 2, selected set of taxonomies for this study was introduced and processes of this study were explained. The results of this study were represented in section 3.

2. Selection and Application of Taxonomies

2.1 Selection of Communication Error Taxonomies

Since inappropriate communications between human operators affect significantly to the safe operation of overall system, many researchers conducted studies to reduce inappropriate communication. Along with these kinds of studies, many researchers also conducted studies about communication error taxonomies in order to deal with the causes and consequences of inappropriate communications especially on large process control systems such as nuclear, railway, aviation, and medical fields.

However, since the pre-developed taxonomies and its descriptions were both different from study by study, it is confused which set of taxonomies are appropriate for certain purpose. Also, since the previously developed taxonomies were focused on report analysis, it is hard to identify the communication error when the study involves verbal protocol data analyses. Therefore, it is necessary to develop a new set of taxonomies that are more suitable for verbal protocol data analyses.

Fortunately, A. R. Kim et al. [2] suggested a new set of taxonomies that is suitable for verbal protocol data analyses by reviewing various studies. The study was integrated the taxonomies suggested from other studies and categorized them according to the simplified one-way communication model, which is represented in Fig. 1, suggested by Y. H. Chung [6]. In this study, this set of taxonomies was used for investigation of communication errors between operators. Table I shows what kind of inappropriate communication types were involved in selected taxonomies and simple descriptions about each subject.

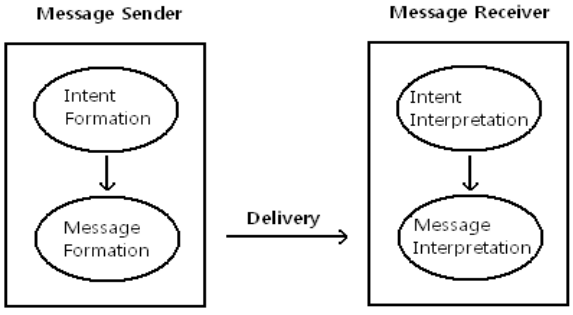

Fig. 1. Simplified one-way communication model [6]

Table I: Selected taxonomies of communication errors [2]

Error Type	Communication error
Type A	Inappropriate message contents
	Phraseology and transposition
Type B	Communication to wrong person
	No communication
	No readback
	Inappropriate readback
	Inappropriate hearback
	Inappropriate hearback type 2
	No response
Type C	Repetition of message
Type D	Inadequate medium
	Miscellaneousness

According to simplified one-way communication model, communication process consists of four factors: message sender, delivery, message receiver, and external factors. Regarding this, communication error can be categorized into four types. Type A errors are the communication errors induced by message sender, and type B errors are the communication errors induced during the delivery process. In the same manner, type C errors are the communication errors induced by message receiver, and type D errors are the communication errors induced by external factors.

Type A errors include two communication error types. Inappropriate message contents means the information contained in the message is inappropriate to the receiver. Phraseology and transposition means the utterance has inappropriate phraseology and transition.

Type B errors include seven communication error types. Communication to wrong person means the message is transmitted to wrong person. No communication means message is not transmitted to the receiver. No readback means the utterance of the sender is not repeated by the receiver. Inappropriate readback means an incorrect repeat of the sender's transmission by the receiver. Inappropriate hearback means the failure to notice or correct a sender's readback error on the sender's part. Inappropriate hearback type 2 means the failure to notice his/her own error in the operators' correct readback on the sender's part. And no response means the cases where a communication does not receive a response.

Type C errors include only one error type: repetition of message. It means the contents of message are repetitive since receiver is misunderstood or does not listen.

Type D errors include two communication error types. Inadequate medium means the communication errors induced by equipment problems. Also, all other communication errors which were not categorized in suggested taxonomies were called as miscellaneousness.

2.2 Application of Taxonomies on Comparative Study between Conventional and Digital MCR

To compare the frequencies and trends of communication errors in conventional MCRs and digital MCRs, it is necessary to collect verbal protocol data. Verbal protocol data is the audio-visual recording data recorded and retrieved from the transient scenarios conducted by real operators in the MCR mock-up simulator. In this study, verbal protocol data both from conventional and digital MCRs was collected, and the transient scenarios of the data were loss of coolant accident (LOCA) scenario and steam generator tube rupture (SGTR) scenario. For conventional MCR data, 9 teams were involved in LOCA scenario and 12 teams were involved in SGTR scenario. For digital MCR data, 3 teams were involved in both types of scenarios.

After the collection of data, it was analyzed one by one to find out how many communication errors were occurred during simulation for each team. Based on the taxonomies introduced before, the occurred communication errors were counted according to each subject.

The results were represented by two parameters. First parameter is ratio of inappropriate communications, which is the ratio of inappropriate communication to total amount of communications during the simulation (except the communications that are not related to simulation). Second parameter is ratio of no communication. Since no communication is uncountable, it is excluded when counting inappropriate communications. Instead, it is measured by comparing the number of communicated steps and the number of total steps in the procedures related to simulation scenario. If operators do not communicate while proceeding some step, it is counted as no communication.

3. Results

By utilizing the selected taxonomies, communication errors during simulation were identified for each team.

In conventional MCRs, 9 teams were involved in LOCA scenario and 12 teams were involved in SGTR scenario. The average ratio of inappropriate communications to total amount of communications was about 20.83%, and the average ratio of no communications to total amount of items in the procedures was about 45.86% for LOCA scenarios. In case of SGTR scenario, the average ratio of inappropriate communications to total amount of communications was about 10.67%, and the average ratio of no communications to total amount of items in the procedures was about 43.77%. Table II and III show the results in conventional MCRs.

Table II: Results in conventional MCRs (LOCA scenario)

Team No.	Ratio of 'inappropriate communication'	Ratio of 'no communication'
1	20.00%	48.84%
2	25.86%	40.00%
3	20.31%	54.13%
4	23.60%	34.48%
5	14.76%	38.54%
6	13.70%	48.57%
7	25.00%	55.56%
8	22.04%	36.96%
9	22.22%	55.65%
Average	20.83%	45.86%

Table III: Results in conventional MCRs (SGTR scenario)

Team No.	Ratio of 'inappropriate communication'	Ratio of 'no communication'
1	10.00%	54.08%
2	5.91%	35.40%
3	11.11%	43.48%
4	6.50%	33.33%
5	13.22%	23.44%
6	9.94%	40.63%
7	5.97%	21.50%
8	13.38%	65.49%
9	13.45%	57.45%
10	11.76%	56.25%
11	9.66%	43.48%
12	17.73%	50.72%
Average	10.67%	43.77%

In digital MCRs, 3 teams were involved in both LOCA and SGTR scenario. The average ratio of inappropriate communications to total amount of communications was about 22.00%, and the average ratio of no communications to total amount of items in the procedures was about 23.18% for LOCA scenarios. In case of SGTR scenario, the average ratio of inappropriate communications to total amount of communications was about 15.97%, and the average ratio of no communications to total amount of items in the procedures was about 20.15%. Table IV and V show the results in digital MCRs.

Table IV: Results in digital MCRs (LOCA scenario)

Team No.	Ratio of 'inappropriate communication'	Ratio of 'no communication'
1	19.38%	22.15%
2	30.68%	29.29%
3	15.93%	18.11%
Average	22.00%	23.18%

Table V: Results in digital MCRs (SGTR scenario)

Team No.	Ratio of 'inappropriate communication'	Ratio of 'no communication'
1	11.81%	19.40%
2	27.05%	10.81%
3	9.88%	30.23%
Average	15.97%	20.15%

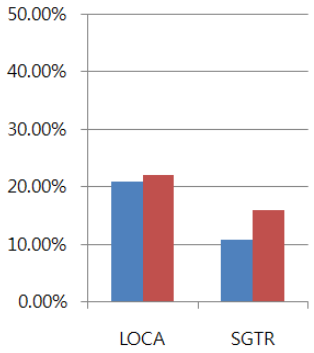

Fig. 2. Average ratio of inappropriate communication in conventional MCRs (blue) and digital MCRs (red)

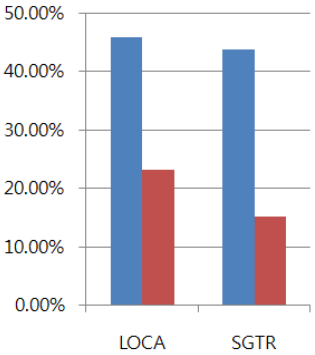

Fig. 3. Average ratio of no communication in conventional MCRs (blue) and digital MCRs (red)

4. Conclusions

In this study, the trends of communication errors in conventional MCRs and digital MCRs were compared. As a result, the average ratio of inappropriate communication in digital MCRs was slightly higher than that in conventional MCRs when the average ratio of no communication in digital MCRs was much smaller than that in conventional MCRs.

Regarding the average ratio of inappropriate communication, it can be inferred that operators are still more familiar to the conventional MCRs than digital MCRs. More case studies are required for more delicate comparison since there were only three examined cases for digital MCRs. However, similar result is expected because there are no differences in communication method, although there are many differences in the way of procedure proceeding.

Regarding the average ratio of no communication, the digital MCRs are much more superior since computerized procedure system; which is widely

installed in digital MCRs, is not able to be proceeded without checking all sub-steps of the procedures, whereas operators can skip some steps based on his/her intuition in conventional MCRs. Therefore, similar result is expected when there are more case-studies.

Since the occurrence of inappropriate communication in digital MCRs are similar to conventional MCRs while the occurrence of no communication in digital MCRs are much smaller than conventional MCRs, it is obvious that digital MCRs are more feasible regarding overall communication processes.

As further works, more case-studies, especially for digital MCR cases are needed for more delicate comparison. Also, since this study does not including the practical solutions for reducing communication errors, it is necessary to find special trend of communication error in digital MCRs and try to solve that problem. The digitalization of MCRs is the worldwide trend, and it is not avoidable. Therefore, continuous studies on enhancing communication processes between operators in digital MCRs should be conducted.

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