

An Experiment on the Impact of Communication Problems in the Multi-cultural Operation of NPPs' Emergency Operation

Seongkeun Kang^{a*}, Jun Su Ha^b, Chanyoung Lee^a, Poong Hyun Seong^a

^a*Dept. of Nuclear and Quantum Engineering, KAIST, Daejeon, Korea*

^b*Dept. of Nuclear Engineering, KUSTAR, Abu Dhabi, UAE*

^{*}*Corresponding author: ksk0618@kaist.ac.kr*

1. Introduction

Several initiatives have recently been taken to provide international cooperation in technology transfer and supplying human factors resources to the nuclear industry worldwide. The aim of promoting international cooperation is for the safe operation of the nuclear power industry. In terms of international cooperation of the nuclear industry, Korean government won a contract of nuclear power plants to UAE government in 2010 and nuclear power plants are now under construction in Barakah, UAE.

However, with technology transfer and international cooperation, there needs to consider several potential problems due to the differences between two culture of the countries such as language, technical culture and expectation. It is unknown how potential problems can lead to an unsafe plant operation as well.

Among of these potential problems, communication is a very important factor in the safe operation of a nuclear power plant. We investigated UAE culture-related issue from analysis of operating experience reviews (OERs) before. We got to know language problem is the main issue from analyzing the OERs.

Korean nuclear power plant operators will work in UAE and they will operate the NPPs with other countries' operators and managers. Therefore they will have to use English when they communicate each other. The purpose of this paper is to confirm how much operators get stress and how much accuracy is declined when operators communicate together in English.

2. Experimental Design

We designed the experiments for finding the effects of communication qualitatively and quantitatively which operators use in English in emergency operation. If an operator works in another country where people can't use his mother tongue, communication problems must be occurred. There are at least five operators such SRO, RO, TO, EO, STA in the main control room (MCR), and there are more workers in site to maintain the nuclear power plants. However we used only three operators and they took a role with SRO, RO, TO in this experiments. All subjects are KAIST students and they can speak and listen in English. Most subjects got TOEIC score more than 800 which is the minimum score to apply UAE site in KHNP.

If the operators or workers are from different countries, they often use English to communicate each

other because English is the world common language. Communication errors can be occurred when people converse with their mother tongue, and even more will be made when the conversation is in a foreign language. Because communicating with other language demand higher mental workload than with mother tongue. Therefore the experiments are designed to confirm how much using foreign language (English) affects on the operators. We considered both quantitatively and qualitatively methods for comparing operators' mental workload. We analyzed four factors to find the communication problems from the experiments which are accuracy, efficiency, NASA-TLX, and brain wave. Accuracy, efficiency, brain wave are quantitative factors, but NASA-TLX is qualitative factor.

We measured accuracy through Bayesian inference. If an abnormal situation occurred, each indicator should change increase, decrease or steady. Operators catch up this changes of indicators by seeing by themselves or listening from other operators and pile up this information to their brain. Because this experiments focus on communication issues so we did not focus on changes of indicator by oneself but focus on changes of indicator by listening from sound of other operators. One operator only listened the information and the rest two operators were speaking the changes of information continuously. If this communication had no problem, then operator could find the right abnormal condition which is correct malfunction by Bayesian inference.

Efficiency is measured by time. We considered that if operators communicate fluently, they can resolve the accident quickly. Therefore we assume that the problem resolution time of the malfunction with communication in Korean take shorter than communication in English.

NASA-TLX is abbreviation of NASA Task Load Index^[1]. This method assesses work load of human on five 7-point scales. Increments of high, medium and low estimates for each point result in 21 gradations on the scales. We can measure six factors which are mental demand, physical demand, temporal demand, performance, effort, frustration. Mental demand means how mentally demanding was the task?, physical demand; how physically demanding was the task?, temporal demand; how hurried or rushed was the pace of the task?, performance; how successful were you in accomplishing what you were asked to do?, effort; how hard did you have to work to accomplish your level of performance, and frustration; how insecure, discouraged, irritated, stressed, and annoyed were you?. So we used NASA-TLX to know how operators feel in each

experiment and we compared the same subject of NASA-TLX between communication in Korean and in English.

Lastly, brain wave was also selected for our factors to find the communication problems. It is a physiological measurement and it has three advantages^[2]. First subjects can be monitored by an array of physiological sensors, some required contact with the subject's body through electrolyte sensors. Second, physiological measures permit a more objective workload assessment and can provide real time evaluation, thus allowing the system designer to quickly and accurately identify usability problems as they occur. Third, it is possible to get detailed analysis of results. One of the analysis method is to divide brain wave type into frequency. We can divide five categories depending on frequency^[3]; delta (0~4Hz), theta (4~8Hz), alpha (8~13Hz), beta (13~30Hz), gamma (30~50Hz) and each frequency has different characteristics. Among of these five waves we chose beta and gamma brainwave and analyzed them. Beta brainwave dominate our normal waking state of consciousness when attention is directed towards cognitive tasks and the outside world. Gamma brainwave are much released when human feels terrible state. Therefore if beta and gamma brain wave of an operator release much more than usual day, we can predict that the operator concentrates his attention on the situation and he feels nervous.

To make nuclear power plants safety, probabilistic safety assessment (PSA) is needed. In addition to analyze PSA, we have to know input factors which are equipment reliability and human reliability. Therefore human reliability method (HRA) is necessary to make nuclear power plants safety^[4]. According to one of the HRA method which is THERP, human error probability (HEP) is calculated considering both diagnosis error and execution error. Therefore we did experiments considering both diagnosis part and execution part.

The experiments are composed two part. One is diagnosis part, the other is execution part. To confirm the effects of communication issues, each part is repeated two times. People use mother tongue to communicate one time and they use only English to communicate in another time. Through comparing this experimental results, we can confirm that how much foreign language affects to operators' mental workload.

3. Results & discussion of Experiment

Experiments were done by ten teams. As we explained experimental design sections, each team did experiments totally four times with two scenarios which are experiment of diagnosis part in Korean and in English, experiment of execution part in Korean and in English. For the making the results of the experiments, we considered accuracy, efficiency, NASA-TLX and brainwave. Among of these four factors, accuracy,

NASA-TLX, brainwave were used in the experiment of diagnosis part because this time (efficiency) of experiment scenario is fixed the same time. On the other hand accuracy was not considered in the experiment of execution case. Because this experiment does not have correct answer.

3.1. Experiment of diagnosis part

-Accuracy:

In terms of accuracy, all teams found the correct malfunction with communication in Korean but six teams (60%) among ten teams found the right malfunction with communication in English.

Table I Correctness of finding right malfunction

Team	Correctness	
	Korean	English
1	o	o
2	o	o
3	o	o
4	o	x
5	o	x
6	o	x
7	o	o
8	o	o
9	o	o
10	o	x

There may be several reasons such as misunderstanding, communication error, etc. However the key reason is that number dialogue is far different. The number of information which is changes of indicator with communication in Korean was more than communication in English. It means that the probability of missing key information is increased when they communicate in English and this missed information can be affected to subjects who make inferences to find the correct malfunction with Bayesian inference.

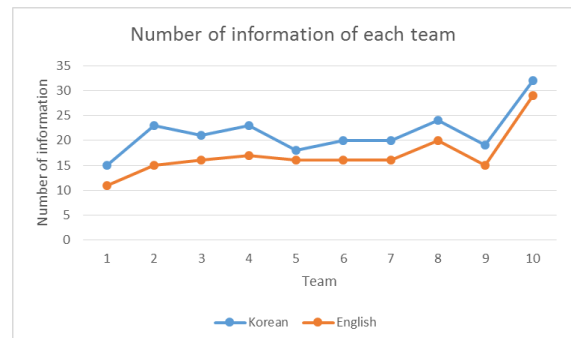


Fig. 1. Number of information of each team

-NASA-TLX:

Among six factors, we analyzed four factors which are mental demand, performance, effort, and frustration. Because physical demand and temporal demand are not related to mental workload with communication problems. The results show that most operators felt higher workload when they communicated in English than in Korean.

Eight teams felt more mental demand when they communicated in English. Two teams felt more comfortable when they use in Korean.

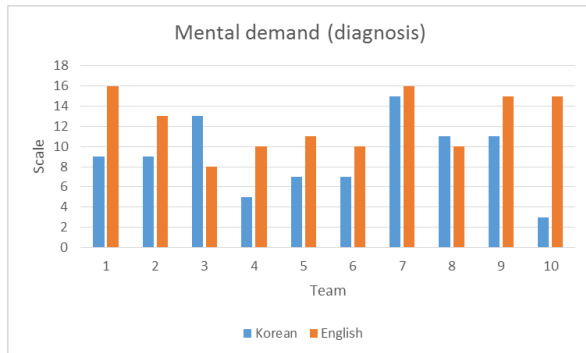


Fig. 2. Mental demand scale of each team in diagnosis part

Only one team thought that they were less successful in accomplishing when they use in English. One team thought that their performance was same with using in Korean and English. Eight teams thought that their performance was better with communicating in Korean than in English.

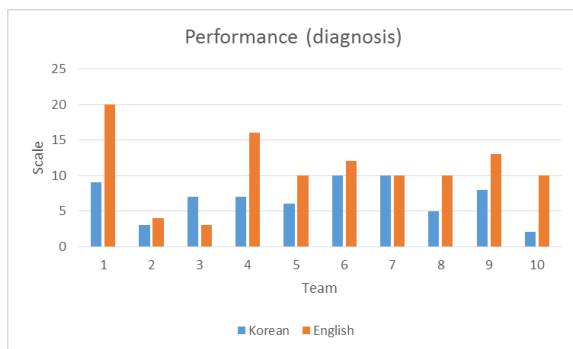


Fig. 3. Performance scale of each team in diagnosis part

In terms of effort, 60% team felt hard to work to communicate in English than Korean, one team worked same effort with communication in Korean and English. 30% team felt easy to work when they communicated in English.

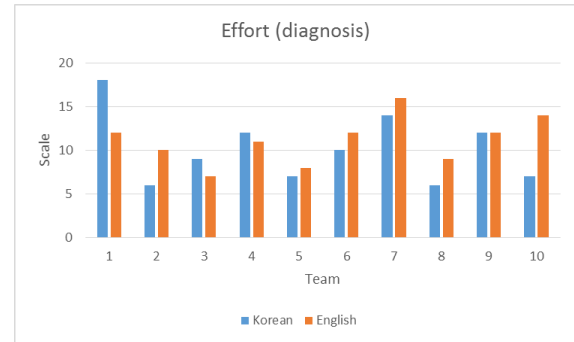


Fig. 4. Effort scale of each team in diagnosis part

The results of frustration is similar as other mental workload factors. 90% team felt insecure, discouraged, irritated, stressed, and annoyed when they communicated in English.

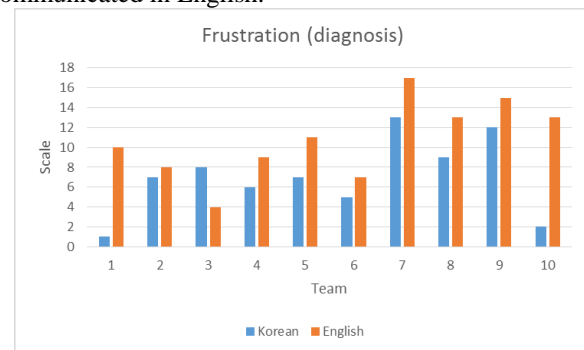


Fig. 5. Frustration scale of each team in diagnosis case

We analyzed NASA-TLX of the experiment of diagnosis case. Around 80% operator team felt more workload when they communicated in English than Korean. They have quite good English grade but they felt high workload with communicating in English.

-Brainwave:

Absolute power of beta brainwave is increased in nine teams among ten teams and absolute power of gamma brainwave is increased in seven teams. We can not conclude which level of absolute power can be a criteria of dividing high mental workload and low mental workload because operators release different amount of brainwave. However we can compare how much workload each operator has between communication in Korean and English. From this results of brainwave, we can conclude that most Korean operators more concentrated and took more attention on communicating in English by analyzing beta brainwave. In addition most of them felt nervous to use in English by analyzing gamma brainwave.

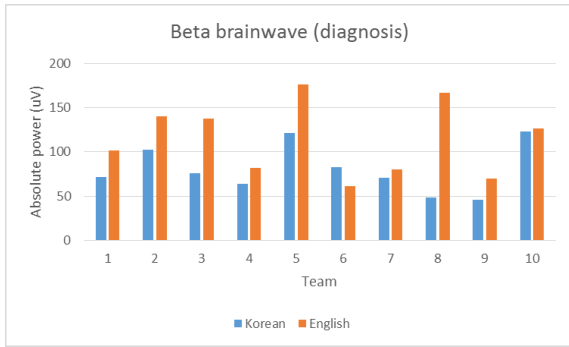


Fig. 6. Beta brainwave of each team in diagnosis part

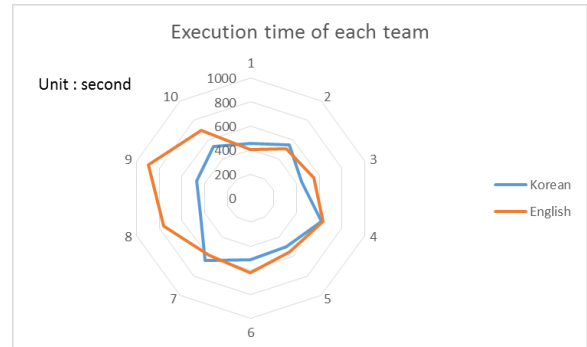


Fig. 8. Execution time of each team in diagnosis case

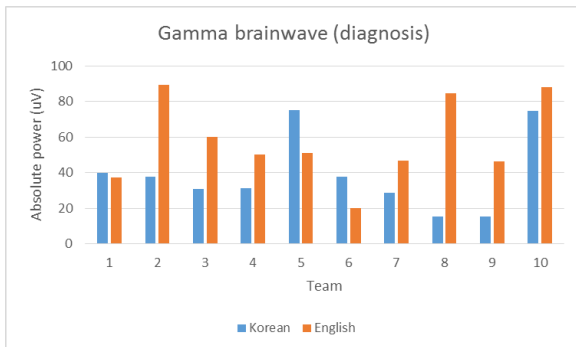


Fig. 7. Gamma brainwave of each team in diagnosis part

3.2. Experiment of execution part

-Efficiency:

To investigate efficiency between operators communicate in Korean and in English, We measured the execution time to resolve the same malfunction scenario for each team. Seven teams took more time to resolve the scenario which communicated in English and three teams took less time when they communicated in English. The noteworthy thing is the gap of time between communication in Korean and English. Three teams who took more time with in Korean to resolve the malfunction scenario do not see a huge time gap. However subjects who took long time with communication in English showed big difference in some teams such as team 8,9,10. We can analyze that most team took similar execution time to resolve the scenario with communication in Korean from 400 second to 600 second. They also took similar time with communication in English in most team. However if they have problem in communication in English, they took time a lot comparing the time of communication in Korean. The teams who have trouble with communication in English have to take steps such as English training, or English communication procedure protocol, etc.

-NASA-TLX:

The results of NASA-TLX in experiment for execution part are similar as the results of diagnosis part. Most teams felt high workload when they communicated in English.

Six teams felt more mental demand when they communicated in English. Three teams felt same mental demand in both language. One team felt more comfortable when they use in Korean.

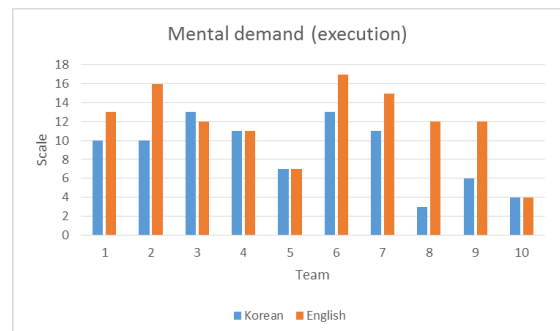


Fig. 9. Mental demand scale of each team in execution part

Only one team thought that they were less successful in accomplishing when they use in English. two teams thought that their performance was same with using in Korean and English. Seven teams thought that their performance was better with communicating in Korean than in English.

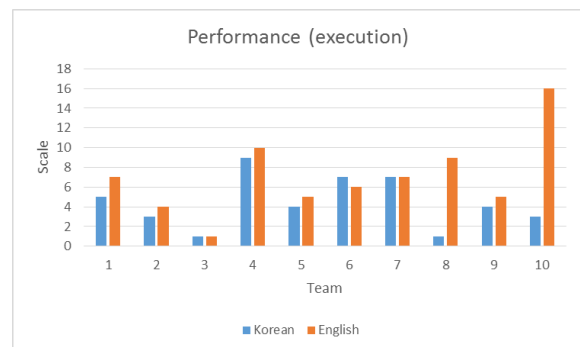


Fig. 10. Performance scale of each team in execution part

In terms of effort, 50% team felt hard to work to communicate in English than Korean, 20% team worked

same effort with communication in Korean and English. 30% team felt easy to work when they communicated in English.

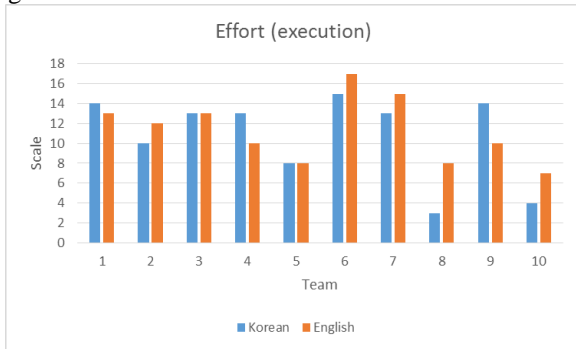


Fig. 11. Effort scale of each team in execution part

The results of frustration are similar as other mental workload factors. 70% team felt insecure, discouraged, irritated, stressed, and annoyed when they communicated in English.

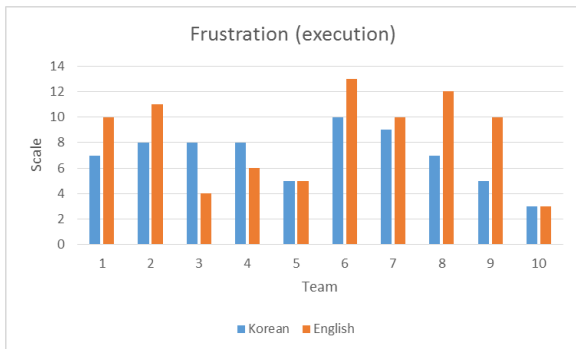


Fig. 12. Frustration scale of each team in execution part

-Brain wave:

Absolute power of beta brainwave was increased in eight teams among ten teams and absolute power of gamma brainwave was increased in nine teams. Both diagnosis case and execution case are displayed same tendency. In the experiment of execution case, subjects concentrated more and took more attention on communicating in English than mother tongue. In addition most of them felt nervous and got stressed to communicate in English.

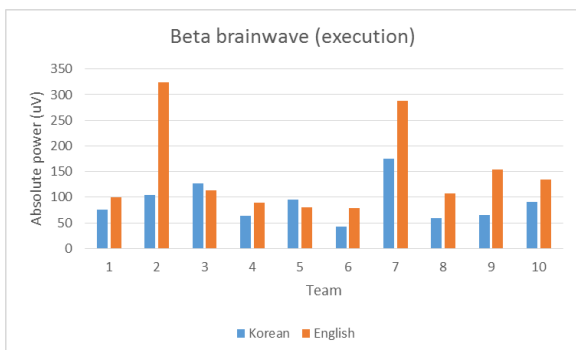


Fig. 13. Beta brainwave of each team in execution part

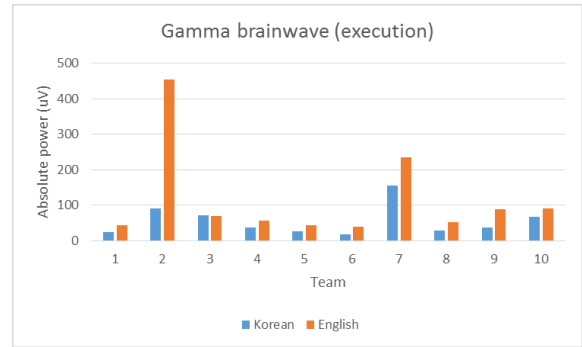


Fig. 14. Gamma brainwave of each team in execution part

4. Conclusion & Summary

Reducing human error is quite important to make nuclear power plants safety. As mental workload of human operator is increased, operators get more stress, then the probability of occurring human error may be increased. It will affect bad influence to nuclear power plants safety. There are many factors to make mental workload increased. We focused on communication problem which is a key factor of the increasing mental workload because many Korean operators will work in UAE nuclear power plants and they may work together with UAE operators.

We designed experimental methods to be able to check this problem qualitatively and quantitatively. We analyzed four factors to find the communication problems from the experiments which are accuracy, efficiency, NASA-TLX, and brain wave. Accuracy, efficiency, brain wave are quantitative factors, and NASA-TLX is qualitative factor.

To find the impact of how much English affects the operators' workload, we did two cases of experiments; one is experiment for diagnosis and the other is experiment for execution.

We expected that subjects will feel high workload when they communicate in English. The results of experiments are also shown what we expected. Both qualitative factor which is NASA-TLX and quantitative factors which are Accuracy, efficiency, and brainwave were indicated subjects felt high workload even though they have a good command of English.

We learned that something is needed to help the Korean operators in terms of communication from this study. Nuclear industry has to learn from other industry such as aviation industry which is streets ahead of degree of internationalization. Studying communication protocol, or systematic English education for operators who work in other country is needed for further study.

REFERENCES

- [1] NASA-TASK LOAD INDEX (NASA-TLX); 20 years later, Sandra G. Hart, 2006
- [2] THE LANCET neurology, 2003
- [3] The unity of life & consciousness, Will Hart, 2014
- [4] An experimental study on estimating human error probability (HEP) parameters for PSA/HRA by using human model simulation, Yoshikawa H, 1999