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Experiments on the Impact of language Problems in the Multi-cultural Operation of NPPs' Emergency Operation

Seongkeun Kang[a*], Taehoon Kim[a], Jun Su Ha[b], 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 foster international cooperation in technology transfer and supplying human factors resources to the nuclear industry worldwide in order to consolidate safety in the nuclear power industry. In 2010, The Korea Electric Power Corporation (KEPCO) was awarded a multi-billion dollar bid to construct the first nuclear power plant in Barakah, UAE.

One must keep in mind however, that with technology transfer and international cooperation comes a host of potential problems arising from cultural differences such as language, everyday habitudes and workplace expectation. As of now, how problematic these potential issues may become is unknown.

Of the aforementioned factors, communication is perhaps of foremost importance. We investigated UAE culture-related issues through analysis of operating experience reviews (OERs) and came to the conclusion that the language barrier needed utmost attention.

Korean nuclear power plant operators will work in UAE and will operate the NPPs with operators and managers of other nationalities as well. Hence, subjecting them to an English-speaking work environment. The purpose of this paper is firstly to confirm that operators are put under mental stress, and secondly to demonstrate the decline in accuracy when they must work in English.

2. Experimental Design

We designed experiments to measure and observe the quantitative and qualitative impact of communication in English between Korean and Emirati operators in an emergency operation There are at least five operators such as SRO, RO, TO, EO, STA in the main control room (MCR) in Korea NPPs, and there are more workers in site to maintain the nuclear power plants. However, we used only three operators - SRO, RO, TO in these experiments. All Korean subjects are KAIST students and all UAE's subjects are Khalifa University students. All of the students participating in the experiment possess an adequate level of fluency in English, whereby the majority of subjects attained a TOEIC(Test of English for International Communication**)** score of at least 800, the minimum threshold score to apply for a post in KHNP in the UAE.

Considering that communication problems often occur when people converse in their mother tongue, it is inevitable that they increase when functioning in a foreign language. This can be attributed to a heightened mental workload when speaking another language. Therefore the experiments are designed to confirm the extent to which using a foreign language (in this case English) affects the operators' work performance We analyzed three quantitative factors – accuracy, efficiency and brain waves and one qualitative factor – the NASA-TLX to correctly diagnose the communication problems occurring in the workplace.

The Bayesian inference method was used to measure accuracy. If an abnormal situation occurs, each indicator should show a change - either increase, decrease or steady. Operators can keep track of the indicators' change through either observation or listening to other operators. The information then accumulates in the operator's brain. As these experiments concern communication issues, we solely focused on indicator change information provided by other operators and excluded those detected through observation. One operator only listened the information and the rest of 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. In a team of three operators, one operator supposed the role of the "listener" and the remaining two continuously reported changes of the indicator through speech. If this communication process worked smoothly, the operator would correctly identify the malfunction in the given abnormal condition.

Efficiency was measured by time. If operators communicate fluently, they can resolve the abnormal situation quickly. Hence we hypothesized that the problem resolution time of a specific malfunction would be shorter when the operator's function in their mother tongue as opposed to English.

NASA-TLX is the abbreviation of NASA Task Load Index[1]. This method assesses the 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. So we used NASA-TLX to gather data about how the operators felt in each experiment – and compared results for communication in Korean and English.

Lastly, we selected brain waves to effectively locate language problems. It is a physiological measurement with three major advantages[2]. First of all, subjects can be monitored by an array of physiological sensors, some required contact with the subject's body through electrolyte sensors. Second, physiological measurements 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 obtain a detailed analysis of results. One of the analysis method is to classify the brain waves by frequency brain wave type into frequency. We end up with five categories demarcated by frequency[3]; delta (0~4Hz), theta (4~8Hz), alpha (8~13Hz), beta (13~30Hz), gamma (30~50Hz) and each frequency has different characteristics. Among these five waves we chose beta and gamma brainwaves and analyzed them. Beta brainwaves dominate our normal waking state of consciousness when attention is directed towards cognitive tasks and the outside world. Gamma brainwaves are the dominantly released when humans are under immense stress. Therefore if a significantly higher amount of beta and gamma brain waves is detected, , we can safely predict that the operator is showing high concentration and is tense

To make nuclear power plants safer, probabilistic safety assessment (PSA) is necessary. In addition to analyzing PSA, we must know input factors such as equipment reliability and human reliability. According to one of the HRA method THERP, human error probability (HEP) is calculated considering both diagnosis error and execution error. Therefore we did experiments considering both the diagnosis execution segments.

The experiments are composed of two parts – the first being the diagnosis and the second execution. To confirm the impacts of communication issues, each part is repeated two times. Subjects used mother tongue to communicate one time and they used only English to communicate in another time. Through comparison of these experimental results, we could confirm the degree to which using a foreign language affects operator performance (including accuracy and mental workload). In addition, we could also compare experimental finding between the Korean and UAE subjects.

3. Results & discussion of Experiment

Experiments were done by ten Korean teams (#1~#10) and five UAE teams (#11~#15). As we explained in the experimental design sections, each team conducted the experiments four times with two separate scenarios which are the diagnosis experiment conducted in the subjects' mother tongue and in English the execution experiment conducted in the two languages. To obtain results of the experiments, we considered accuracy, efficiency, NASA-TLX and brainwave. Among these four factors, accuracy, NASA-TLX, brainwave were used in the diagnosis experiment because this time (efficiency) of experiment scenario is fixed. On the other hand, accuracy was not considered in the execution experiment case. Because this experiment does not have a correct answer.

3.1. Experiment of diagnosis part

-Accuracy:

In terms of accuracy, all Korean teams identified the correct malfunction when communicating in Korean but only six teams (60%) among were able to find the correct malfunction when communicating in English. 80% of UAE team found the correct malfunction when they communicated in their mother tongue but 60% found the correct malfunction when they communicated in English.

Table I Correctness of finding correct malfunction

Team	Correctness	
	Mother tongue	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
11	o	x
12	o	o
13	x	x
14	o	o
15	o	o

There may be several reasons such as misunderstanding, communication error, etc. for these results. However the key reason is the quantity of dialogue that occurred amongst the operators. In all of the teams it was found that more information was relayed when the communicators functioned in their mother tongue. This shows that the probability of missing key information undoubtedly increases when communication is done in English, leading to weak inferences which become the basis to finding the correct malfunction using Bayesian inference.

-NASA-TLX:

Fourteen teams got a higher score on NASA-TLX. The results show that most operators felt a higher workload when they communicated in English than in their mother tongue.

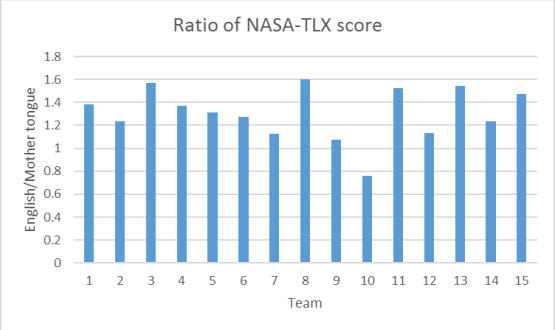

Fig. 1. Ratio of NASA-TLX score of each team in diagnosis part

Only one team (Team #10) thought that they felt less workload when they used English.

We analyzed NASA-TLX of the diagnosis experiment case. Around 99.33% of the operator team felt more of a workload when they communicated in English than in their mother tongue. They had a reasonably high English grade on the standardized test, but felt a high workload when working in English all the same.

-Brainwave:

The absolute power of beta brainwave was increased in nine teams of Korean subjects and in all UAE teams subjects among five teams. For the gamma brainwave, the absolute power was increased in seven teams among Korean operators and in all UAE teams. We cannot conclude which level of absolute power can be a criteria of dividing high mental workload and low mental workload because operators released different amounts of brainwave. However, we can compare the operator's respective workload in their mother tongue and in English. Through analysis of beta brainwaves we can conclude that most Korean and UAE operators concentrated more and were more alert when communicating in English. Gamma brainwaves show that they were also highly nervous when using English.

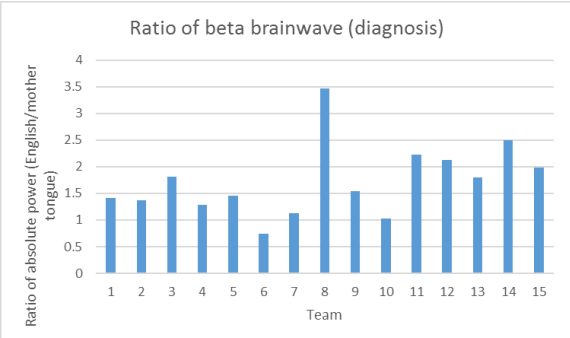

Fig. 2. Ratio of beta brainwave of each team in diagnosis part

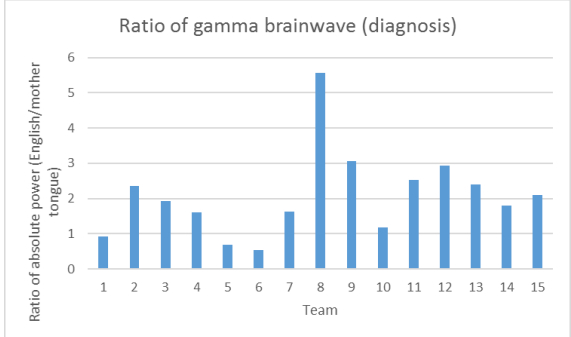

Fig. 3. Ratio of gamma brainwave of each team in diagnosis part

3.2. Experiment of execution part

-Efficiency:

To investigate efficiency between operators communicating in English and in their mother tongue, we measured the execution time to resolve the same malfunction scenario for each team. Most teams took longer to resolve the scenario when communicating in English and only three teams took less time when they communicated in English. It is worth noting the time gap in communication in these two languages. In the three teams who took more time within the mother tongue group do not show a huge time gap in the resolution of the malfunction scenario. However, subjects who took long time with communication in English showed a big difference as shown by teams 8,9,11 and 13. We can say that most teams took similar execution time to resolve the scenario when communicating in their mother tongue from 400 to 600 seconds. They also took similar time when communicating in English. However if they encounter a problem when communicating in English, they took relative longer compared to when communicating in their mother tongue. The teams who had trouble communicating in English must take steps such as English training, or English communication procedure protocol, etc.

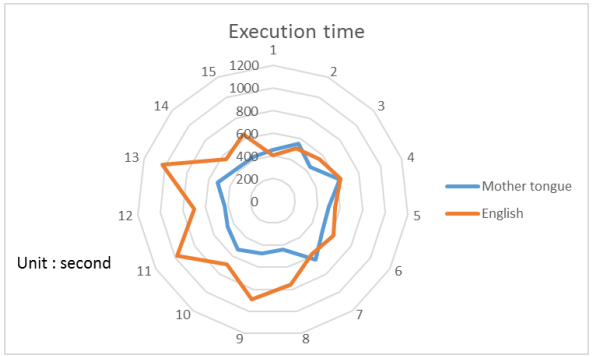

Fig. 4. Execution time of each team in execution part

-NASA-TLX:

The results of NASA-TLX in the execution experiment are similar to the diagnosis results. Most teams felt a higher workload when they communicated in English.

Twelve teams felt a higher mental demand when they communicated in English. One team felt the same mental demand in both languages. Two teams felt more comfortable when they used Korean.

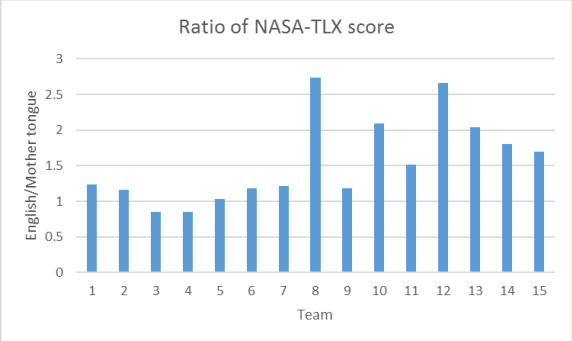

Fig. 5. Ratio of NASA-TLX score of each team in execution part

In terms of NASA-TLX, 80% of the team felt it was harder to work and communicate in English than in their mother tongue in the execution phase of the experiment.

Furthermore, as we explained in experiment design paragraph, Korean subjects were allocated in team #1~#10 and UAE subjects were allocated in team #11~15. We can analyze that UAE subjects felt more workload than Korean subjects from the NASA-TLX score results.

-Brain wave:

Measuring and analyzing brain wave of experiment for execution part is only done by Korean subjects. The brain waves for the execution phase of UAE subjects will be analyzed for further work. The 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 and execution cases displayed the same tendency. In the execution experiment case, subjects concentrated more and paid more attention on communicating in English than in their mother tongue. In addition most of them felt nervous and got stressed when communicating in English.

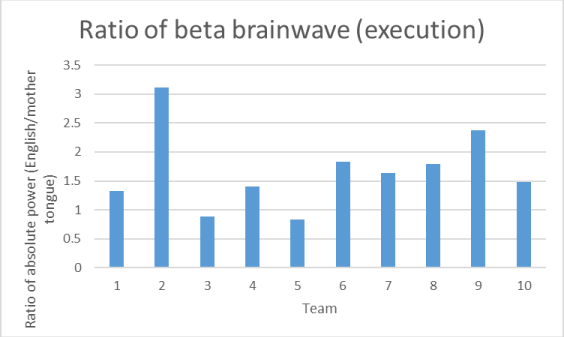

Fig. 6. Beta brainwave of each team in execution part

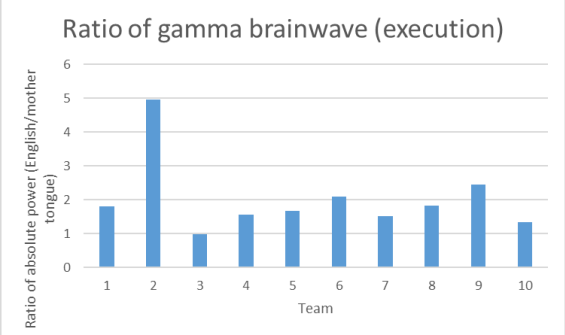

Fig. 7. Gamma brainwave of each team in execution part

4. Conclusion & Summary

Reducing human error is quite important to make nuclear power plants safer. As the mental workload of human operator is increased, the probability of a human error occurring also increases. It will have a negative influence on the plant's safety. There are many factors which can potentially increase mental workload. We focused on communication problem which is a key factor of increasing mental workload because many Korean operators will work in UAE nuclear power plants and may work together with UAE operators. From these experiments we compared how performance of both Korean and UAE subjects were decreased when they use English. In addition, we also compared performance between Korean and UAE subjects.

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 measure how much of an the impact English has on the operators' workload, we divided the experiment into two cases; one is experiment for diagnosis and the other is experiment for execution.

We expected that subjects would feel a higher workload when they communicate in English. The results of experiments match what we expected. Both the qualitative factor(NASA-TLX) and quantitative factors

which are accuracy, efficiency, and brainwave indicated that subjects felt a higher workload even though they had a good command of English.

Through this study, we learned that additional help or guidance must be put in place to help the Korean operators in terms of communication. The nuclear industry must take the example of other industries such as the aviation industry, which is doing well in terms of providing an internationalized work environment Studying communication protocol, or implementing systematic English education for operators who work overseas is needed for further study.

Acknowledgement

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