Experiments for Evaluating Application of Bayesian Inference to Situation Awareness of Human Operators in NPPs

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1. Introduction

Bayesian methodology has been widely used in various research field. It is a method of inference using Bayes' rule to update the estimation of probability for the certain hypothesis when additional evidences are acquired. According to one of the researches about the Bayesian inference, malfunctions of nuclear power plants can be detected by ideal operator, who piles up the newly incoming data and updates its estimation.[1]

The purpose of this paper is to confirm if Bayesian inference can properly reflect the situation awareness of real human operators, and find the difference between the situation of ideal and practical operators, and investigate the factors which contributes to those difference.

2. Experimental Design

The experiment was conducted by using CNS (Compact Nuclear Simulator) which is simulation of Westinghouse three loop type.

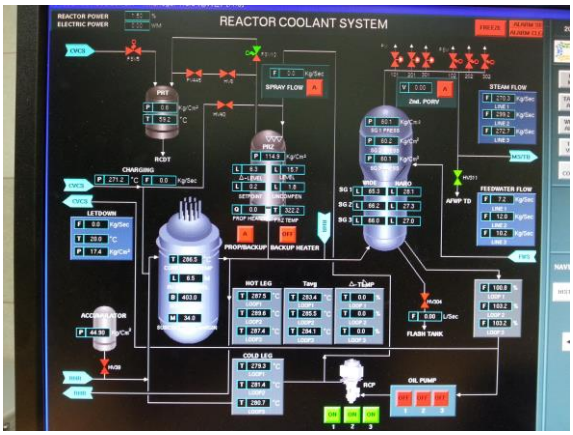

Fig. 1. Screen of RCS

Subjects monitor RCS(Reactor Coolant System) built in graphics of the CNS. It includes two stages of difficulties. Subjects of experiments are both surveying and recording the loud speaking.

CNS is equipped with 88 malfunctions. Among them, five malfunctions (Drop of all control rods in CBA, Rod bank uncontrolled in, ATWS, PRZ PORV stuck open, PRZ spray valve open, fails to close or jammed shut) are chosen for simple experiments, and eleven malfunctions (Drop of all control rods in CBA, Drop of all single control rod in CBA, Rod bank uncontrolled in, Operation blocked, ATWS, PRZ PORV stuck open, PRZ SV stuck open, PRZ spray valve open, fails to close or jammed shut, Failure in PRZ pressure controller, Steam dump valves open undemanded, undemanded turbine control valve movements) are chosen for complex ones.

All of malfunctions have different effects (symptoms). Table 1 shows those malfunctions and effects.

Table I: Malfunctions and Effects

	PRZ P	PRZ L	Backup heater	Rx trip	Turbine trip	PRT T	PRT P	Avg T	HV 304	HV 6	RCP
Drop of all control rods in CBA	dec	dec	o	o	o	s	s	dec	s	off	s
Drop of all single control rod in CBA	dec	dec	o	x	x	s	s	s	s	s	s
Rod bank uncontrolled in	dec	dec	o	o	o	s	s	inc	s	s	s
Operation blocked	inc	inc	s	x	x	s	s	dec	s	s	s
ATWS	inc, dec	inc, dec	s	o	o	s	s	inc	s	s	s
PRZ PORV stuck open	dec	dec,inc	o	o	o	inc	inc	inc,dec	s	s	s
PRZ SV stuck open	dec	dec	o	o	o	inc	inc	inc,dec	s	off	s
PRZ spray valve open, fails to close or jammed shut	dec	dec,inc	o	o	o	s	s	s	s	off	s
Failure in PRZ pressure controller	dec	inc	o	o	o	s	s	s	s	off	s
Steam dump valves open undemanded	dec	dec	o	o	o	s	s	dec	s	off	s
Undemanded turbine control valve movement	inc, dec	inc, dec	o	o	o	inc	inc	inc	s	off	s

'o' means on or open, 'dec, inc' or 'inc, dec' means decrease and increase continuously or increase and decrease continuously, and 's' indicates steady.

The procedure of the experiments are described as follows :

1) The specific malfunction is given to the CNS, and it affects to NPPs and changes measuring instruments such as PRZ pressure, valve opening, SG level, etc.

2) During the virtual situations of few minutes, subjects are supposed to say and remember what they see continuously.
3) After the situations are over, subjects are asked to check the prepared survey about the previous virtual situation.
4) Finally subjects are asked to find the right malfunction by checking the right one between multiple choices.

The total number of subjects are 31, and all of them are affiliated in engineering or natural science in KAIST. Before the experiments starts, subjects spend 20~30 minutes to get accustomed to the screen of RCS. Usually spending time about 20 minutes, subjects learn where the valves are, what the value of PRZ level in normal operation is, Backup heater is on or off, etc.

3. Calculation of Theoretical Probability

Ideal operators whose brain is like a computer can memorize all the information what they saw, and can do calculation perfectly with Bayesian methodology.

There are five malfunctions, and assuming each malfunction has probability of occurrence 0.0001. Table 4 shows the sensor, and On-Off error.[1]

Table II: Probability of each malfunction in simple experiment

Number	Normal	number 1	number 5	number 7	number 8	number 11
Malfunction	Normal	Drop of all control rods in CBA	Rod bank uncontrolled in	ATWS	PRZ PORV stuck open	PRZ spray valve open, fails to close or jammed shut
probability	0.9995	0.0001	0.0001	0.0001	0.0001	0.0001

Table III: Probability of each malfunction in complex experiment

Number	Normal	number 1	number 2	number 5	number6	number7
Malfunction	Normal	Drop of all control rods in CBA	Drop of all single control rod in CBA	Rod bank uncontrolled in	Operation blocked	ATWS
Probability	0.9989	0.0001	0.0001	0.0001	0.0001	0.0001
Number	number 8	number 9	number 11	number 12	number 13	number 14
Malfunction	PRZ PORV stuck open	PRZ SV stuck open	PRZ spray valve open, fails to close or jammed shut	Failure in PRZ pressure controller	Steam dump valves open undemanded	Undemanded turbine control valve movement
Probability	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001

Table IV: Sensor and On-Off error

Sensor error	Normal	fail-high	stuck at steady	fail-low
Probability	0.999	0.0001	0.0008	0.0001
On-Off error	Normal	fail-on	stuck at steady	fail-off
Probability	0.999	0.0001	0.0008	0.0001

Final probability is obtained by using Bayesian updating referenced by table 2 and table 4.

1) Calculating probability in simple case, and finding the right malfunction. Seven information is updated to the ideal operator, and the ideal operator calculates the probability of each malfunctions when every new information is acquired such as 'backup heater on', 'PRZ level decrease', etc.
The below table (Table 5) shows how probability is changing, and which malfunction is the right answer.
According to the table 5, when ideal operator receives all of the information (seven indicators), they consider that 'PRZ PORV stuck open' is the right malfunction by 100% chance.

Table V: Theoretic probability of simple experiment

		Normal	Drop of all control rods in CBA	Rod bank uncontroll ed in	ATWS	PRZ PORV stuck open	PRZ spray valve open, fails to close or jammed shut
Initial condition		9.9950E-01	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04	1.0000E-04
Rx trip	on	1.6672E-01	1.6666E-01	1.6666E-01	1.6666E-01	1.6666E-01	1.6666E-01
Turbine trip	on	2.1748E-02	1.9565E-01	1.9565E-01	1.9565E-01	1.9565E-01	1.9565E-01
Backup heater	on	2.7813E-06	2.4999E-01	2.4999E-01	2.5022E-05	2.4999E-01	2.4999E-01
PRZ L	dec	3.7116E-10	3.3331E-01	3.3331E-01	3.3361E-05	3.3331E-01	3.3361E-05
PRZ L	inc	1.1142E-13	1.0006E-04	1.0006E-04	1.0006E-04	9.9970E-01	1.0015E-08
PRZ P	dec	1.1153E-17	1.0007E-04	1.0007E-04	1.0016E-08	9.9980E-01	1.0016E-08
PRT T	inc	1.1166E-21	1.0018E-08	1.0018E-08	1.0027E-12	1.0000E+00	1.0027E-12

2) The procedure of experiment containing complex situations are same to that of simple one.

Table VI: Theoretic probability of complex experiment

		Normal	Drop of all control rods in CBA	Drop of all single control rod in CBA	Rod bank uncontrol led in	Operatio n blocked	ATWS
initial condition		0.9989	0.0001	0.0001	0.0001	0.0001	0.0001
PRZ P	dec	0.090892	0.09091	0.09091	0.09091	9.1E-06	0.09091
RCP	steady	0.090892	0.09091	0.09091	0.09091	9.1E-06	0.09091
HV304	steady	0.090892	0.09091	0.09091	0.09091	9.1E-06	0.09091
Turbine trip	on	1.11E-05	0.111109	1.11E-05	0.111109	1.11E-09	0.111109
Rx trip	on	1.11E-09	0.111111	1.11E-09	0.111111	1.11E-13	0.111111
Backup heater	on	1.25E-13	0.124998	1.25E-09	0.124998	1.25E-17	1.25E-05
PRZ L	dec	1.43E-17	0.142853	1.43E-09	0.142853	1.43E-21	1.43E-05
PRT T	inc	3.35E-21	3.34E-05	3.34E-13	3.34E-05	3.35E-25	3.34E-09
PRT P	inc	3.35E-25	3.34E-09	3.35E-17	3.34E-09	3.35E-29	3.34E-13
HV 6	off	5.03E-29	5.01E-13	5.02E-21	5.01E-13	5.04E-33	5.02E-17
Avg T	inc	5.03E-33	5.01E-13	5.02E-21	5.01E-13	5.04E-33	5.02E-17
Avg T	dec	1.01E-36	1E-12	1.01E-24	1E-16	1.01E-32	1E-20
		PRZ PORV stuck open	PRZ SV stuck open	PRZ spray valve open, fails to close or jammed shut	Failure in PRZ pressure controller	Steam dump valves open undeman ded	Undeman ded turbine control valve movemen t
initial condition		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
PRZ P	dec	0.09091	0.09091	0.09091	0.09091	0.09091	0.09091
RCP	steady	0.09091	0.09091	0.09091	0.09091	0.09091	0.09091
HV304	steady	0.09091	0.09091	0.09091	0.09091	0.09091	0.09091
Turbine trip	on	0.111109	0.111109	0.111109	0.111109	0.111109	0.111109
Rx trip	on	0.111111	0.111111	0.111111	0.111111	0.111111	0.111111
Backup heater	on	0.124998	0.124998	0.124998	0.124998	0.124998	0.124998
PRZ L	dec	0.142853	0.142853	0.142853	1.43E-05	0.142853	0.142853
PRT T	inc	0.333289	0.333289	3.34E-05	3.34E-09	3.34E-05	0.333289
PRT P	inc	0.333333	0.333333	3.34E-09	3.34E-13	3.34E-09	0.333333
HV 6	off	5E-05	0.499975	5.01E-09	5.01E-13	5.01E-09	0.499975
Avg T	inc	5E-05	0.499975	5.01E-09	5.01E-13	5.01E-09	0.499975
Avg T	dec	0.0001	0.9998	1E-12	1E-16	1E-08	0.0001

Theoretical value of complex experiment can be also obtained, and it is shown in table 6. The complex experiment has eleven malfunctions and eleven instrument indicators.

According to table 6, ideal operator would be thought 'PRZ SV stuck open' is the malfunction with 99.98%.

4. Results of Experiment

4.1. Simple experiment

Total number of subjects are 31, and they are described in 'section 2. Experiment'. Table 7 is the result of the simple experiment. In this table, remembering part shows the answers what the subjects choose. This experiment takes 2m 50s. At the end of the experiment, they choose the changes of the indicator which is increased or decreased, on or off, stuck at steady, don' know. Empty cell means 'don't know'. Mark part shows the answers of subjects are correct or not. Saying part checks what they saw, and how many times they saw the each indicator. For example subject 1, he spoke PRT temperature is now increasing 4 times, PRZ P is decreasing 3times, level is decreasing 2 times, and backup heater on 2 times during the 2m 50s.

Note that subject 1 has only 11 notification among the total events. This may seem little for three minutes observation. It is because there are whole 48 categories to check in the whole survey sheet such as RCP on/off, Rx T_{avg}, SG level, etc. The subjects are told that certain eight indicators are important in advance the experiment.

The correct answer for the experiment is malfunction #8 : 'PRZ PORV stuck open'. The number of subjects who chose the right answer is twenty. Therefore the probability of finding the right malfunction is 20/31 = 64.52%, which is quite lower than the probability of theoretical expectation, 100%.

Table VII: Result of simple experiment

		PRT		PRZ			Backup heater	Rx trip	Turbine trip	Answer sheet
		pressure	temperature	pressure	level	temperature				
Answer		inc	inc	dec	dec,inc	dec	o	y	y	**8**
subject 1	Remembering	dec	inc	dec	dec	inc	on	y	y	**8**
	mark	x	o	o	△	x	o	o	o	**o**
	saying	x	inc 4	de 3	de 2	x	on 2	x	x	
subject 2	Remembering	dec	don't	dec	don't	don't	on	n	n	**1,5**
	mark	x	x	o	x	x	o	x	x	**x**
	saying			dec			on			
subject 3	Remembering					inc	on	y	y	**?**
	mark	x	x	x	x	x	o	o	o	**x**
	saying	x	inc 4				on			
subject 4	Remembering	inc	inc	dec	inc	inc	on	no	no	**8**
	mark	o	o	o	△	x	o	x	x	**o**
	saying	inc	inc 2	dec		dec	on			
subject 5	Remembering	inc	dec	dec	s	don't	s	y	y	**?**
	mark	o	x	o	x	x	x	o	o	**x**
	saying	dec	inc 2	de 2		de 2	on	y		
subject 6	Remembering	dec	dec	s	dec	don't	on	don't	don't	**1,5**
	mark	x	x	x	△	x	o	x	x	**x**
	saying		inc	dec			on			
subject 7	Remembering	dec	dec	dec	dec	dec	on	no	no	**5**
	mark	x	x	o	△	o	o	x	x	**x**
	saying	s	inc	dec	s		on			
subject 8	Remembering	dec	dec	dec	don't	inc	on	no	no	**1,5**
	mark	x	x	o	x	x	o	x	x	**x**
	saying		inc 4	de 4			on			
subject 9	Remembering	inc	inc	inc	don't	don't	on	no	no	**8**
	mark	o	o	x	x	x	o	x	x	**o**
	saying	inc	inc	dec			on			
subject 10	Remembering	s	inc	dec	dec	dec	on	y	y	**1,5**
	mark	x	o	o	△	o	o	o	o	**x**
	saying		inc	de 2	dec	dec	on			
subject 11	Remembering	inc	inc	s	s	don't	on	y	y	**8**
	mark	o	o	x	x	x	o	o	o	**o**
	saying	inc	inc 2				on	y	y	
subject 12	Remembering	don't	don't	inc	don't	dec	on	y	y	**1,5**
	mark	x	x	x	x	o	o	o	o	**x**
	saying			dec		dec	on			
subject 13	Remembering	s	inc	inc	inc	s	on	y	y	**8**
	mark	x	o	x	△	x	o	o	o	**o**
	saying		inc 3	de 2		dec	on			
subject 14	Remembering	inc	inc	inc	inc	inc	o	y	y	**8**
	mark	o	o	x	△	x	o	o	o	**o**
	saying	inc	inc 5	de 3		de 3	on	y	y	
subject 15	Remembering	dec	dec	dec	dec	dec	on	y	y	**1,5**
	mark	x	x	o	△	o	o	o	o	**x**
	saying	s	inc 2	de 3	de 2	de 3		y	y	
subject 16	Remembering	inc	inc	dec	s	s	on	y	y	**8**
	mark	o	o	o	x	x	o	o	o	**o**
	saying		inc 3	dec	s 2		on	y	y	
subject 17	Remembering	s	inc	dec	don't	don't	on	no	y	**8**
	mark	x	o	o	x	x	o	x	o	**o**
	saying		inc 2	dec		de 2	on			
subject 18	Remembering	inc	inc	dec	dec	inc	on	y	y	**8**
	mark	o	o	o	△	x	o	o	o	**o**
	saying			de 2	s	s	on	y	y	
subject 19	Remembering	s	inc	inc	inc	inc, dec	on	y	y	**8**
	mark	x	o	x	△	△	o	o	o	**o**
	saying	s	inc	dec	dec, inc 2	dec	on			
subject 20	Remembering	inc	inc	dec	dec	dec	on	y	y	**8**
	mark	o	o	o	△	o	o	o	o	**o**
	saying	inc 3	inc 5	dec	inc	dec	on			
subject 21	Remembering	don't	inc	inc	dec	inc	on	y	y	**8**
	mark	x	o	x	△	x	o	o	o	**o**
	saying		inc	dec	dec	dec				
subject 22	Remembering	inc	inc	dec	dec	dec	on	y	y	**8**
	mark	o	o	o	△	o	o	o	o	**o**
	saying	inc	inc	dec	don't	dec	on 2			
subject 23	Remembering	inc	inc	dec	dec	dec	on	y	y	**8**
	mark	o	o	o	△	o	o	o	o	**o**
	saying		inc2	de 2			on	y	y	
subject 24	Remembering	s	inc	don't	dec	dec	on	y	y	**8**
	mark	x	inc	x	△	o	o	o	o	**o**
	saying		inc3	de 3	de 2	ec, inc	on			
subject 25	Remembering	inc	inc	inc	don't	inc	don't	y	y	**7**
	mark	o	o	x	x	x	x	o	o	**x**
	saying	inc	inc 2	dec		dec				
subject 26	Remembering	dec	dec	don't	don't	don't	on	y	y	**1**
	mark	x	x	x	x	x	o	o	o	**x**
	saying				dec		on			

subject 27	Remembering	inc	inc	dec	dec	dec	on	don't	don't	**8**
	mark	o	o	o	△	o	o	x	x	**o**
	saying	inc 3	inc 3	de 3	dec	de 3	on			
subject 28	Remembering	s	inc	inc	s	dec	on	don't	don't	**8**
	mark	x	o	x	x	o	o	x	x	**o**
	saying	dec	inc	dec						
subject 29	Remembering	inc	don't	inc	don't	don't	on	y	y	**8**
	mark	o	x	x	x	x	o	o	o	**o**
	saying		inc 2	de 2	inc 2		on			
subject 30	Remembering	inc	inc	dec	inc	don't	on	y	y	**8**
	mark	o	o	o	△	x	o	o	o	**o**
	saying	inc3	inc4	de 3	de 3		on			
subject 31	Remembering	inc	inc	dec	inc	s	on	y	y	**8**
	mark	o	o	o	△	x	o	o	o	**o**
	saying	inc2	inc3	de 3	dec, inc2	de 2	on	y	y	

4.2. Complex experiment

The procedure of complex experiment is same to the simple one. The difference is the number of malfunction increased to eleven, and also the experiment time is reduced to one minutes. Finally, the number of measuring instrument which subjects have to observe is increased to eleven.

According to table 8, sixteen subjects found the right malfunction. Probability of finding malfunction for complex experiment is 16/31 = 51.61%. Like the preceding simple experiment, the gap between real and ideal operator is very large. The complex experiment has even lower probability than simple one.

Table VIII: Result of complex experiment

		valve		PRT		PRZ			Reactor			RCP			Back up heater	Rx trip	Turbine trip	**Answer sheet**
		HV304	HV6	pressure	temperature	pressure	level	temperature	1_T avg	2_T avg	3_T avg	1	2	3				
Answer		s	off	inc	inc	dec	dec	dec	inc, dec	inc, dec	inc, dec	s	s	s	on	y	y	**9**
subject 1	Remembering	s	off	don't	don't	dec	dec	don't	dec	dec	dec	s	s	s	on	y	y	**1,13**
	mark	o	o	x	x	o	o	x	△	△	△	o	o	o	o	o	o	**x**
	saying	x	x	x	inc	dec	x	x	dec	dec	dec	x	x	x	on	x	x	
subject 2	Remembering	s	off	don't	don't	s	s	s	s	s	s	s	s	s	on	y	y	**11**
	mark	o	o	x	x	x	x	x	x	x	x	o	o	o	o	o	o	**x**
	saying		off												on	y	y	
subject 3	Remembering	s	off	s	inc	inc	dec	don't	don't	don't	don't	s	s	s	on	y	y	**9**
	mark	o	o	x	o	x	o	x	x	x	x	o	o	o	o	o	o	**o**
	saying		off	s	inc	de	de		s	s	s				on	y	y	
subject 4	Remembering	s	off	inc	inc	dec	inc	s	dec	dec	dec	s	s	s	on	y	y	**9**
	mark	o	o	o	o	o	x	x	△	△	△	o	o	o	o	o	o	**o**
	saying		off	inc	inc	dec			dec	dec	dec				on			
subject 5	Remembering	s	s	dec	dec	don't	dec	s	dec	s	s	s	s	s	on	no	no	**2**
	mark	o	x	x	x	x	o	x	△	x	x	o	o	o	o	x	x	**x**
	saying			inc	inc	de 2	de 2	de 2	dec	dec	dec				on			
subject 6	Remembering	don't	don't	dec	don't	don't	don't	don't	dec	dec	dec	don't	don't	don't	on	y	y	**8**
	mark	x	x	x	x	x	x	x	△	△	△	x	x	x	o	o	o	**x**
	saying				inc	dec			dec	dec	dec				on			
subject 7	Remembering	s	off	s	dec	dec	s	dec	s	s	s	s	s	s	on	don't	don't	**11**
	mark	o	o	x	x	o	x	o	x	x	x	o	o	o	o	x	x	**x**
	saying			s	inc	dec	s	dec							on			
subject 8	Remembering	s	s	s	dec	dec	s	s	s	s	s	s	s	s	off	y	y	**5**
	mark	o	o	x	x	o	x	x	x	x	x	x	x	x	x	o	o	**x**
	saying				inc	dec									on	y	y	
subject 9	Remembering	s	off	s	inc	inc	inc	inc	dec	dec	dec	s	s	s	on	no	no	**6**
	mark	o	o	x	o	x	x	x	△	△	△	o	o	o	o	x	x	**x**
	saying		off		inc	dec	dec	dec							on			
subject 10	Remembering	s	off	dec	inc	don't	don't	don't	s	s	s	s	s	s	on	y	y	**9**
	mark	o	o	x	o	x	x	x	x	x	x	o	o	o	o	o	o	**o**
	saying					dec									on			

subject 11	Remembering	off	off	inc	inc	dec	don't	don't	s	s	s	s	s	s	on	y	y	**11**
	mark	x	o	o	o	o	x	x	x	x	x	o	o	o	o	o	o	**x**
	saying		off			dec									on	y	y	
subject 12	Remembering	off	off	s	s	don't	don't	don't	dec	dec	dec	s	s	s	on	no	no	**13**
	mark	x	o	x	x	x	x	x	△	△	△	o	o	o	o	x	x	**x**
	saying		off						dec	dec	dec				on			
subject 13	Remembering	s	s	s	inc	dec	dec	dec	dec	dec	dec	s	s	s	on	y	y	**8**
	mark	o	x	x	o	o	o	o	△	△	△	o	o	o	o	o	o	**x**
	saying				inc 2	de 2	dec	dec	dec	dec	dec				on			
subject 14	Remembering	s	off	inc	inc	dec	dec	dec	s	s	s	s	s	s	on	y	y	**9**
	mark	o	o	o	o	o	o	o	△	△	△	o	o	o	o	o	o	**o**
	saying				inc 2	dec		dec	s	s	s				on	y	y	
subject 15	Remembering	s	off	s	inc	inc	inc	inc	s	s	s	s	s	s	on	y	y	**12**
	mark	o	o	x	o	x	x	x	x	x	x	o	o	o	o	o	o	**x**
	saying	s	off	s	inc	dec	dec	dec	s	s	s	s	s	s	on			
subject 16	Remembering	s	off	s	inc	dec	don't	don't	s	s	s	s	s	s	on	y	y	**9**
	mark	o	o	x	o	o	x	x	x	x	x	o	o	o	o	o	o	**o**
	saying				inc	dec			s	s	s				on	y	y	
subject 17	Remembering	s	s	inc	inc	inc	dec	inc	dec	dec	dec	s	s	s	on	no	no	**14**
	mark	o	x	o	o	x	o	x	△	△	△	o	o	o	o	x	x	**x**
	saying		off		inc	dec		dec							on			
subject 18	Remembering	s	off	dec	inc	don't	don't	don't	dec	dec	dec	s	s	s	on	y	y	**14**
	mark	o	o	x	o	x	x	x	△	△	△	o	o	o	o	o	o	**x**
	saying					dec			dec	dec	dec				on			
subject 19	Remembering	s	off	inc	inc	don't	inc	don't	dec	dec	dec	s	s	s	on	y	y	**14**
	mark	o	o	o	o	x	x	x	△	△	△	o	o	o	o	o	o	**x**
	saying	s	off	s	inc							s	s	s	on			
subject 20	Remembering	s	off	inc	inc	dec	dec	dec	dec	dec	dec	s	s	s	on	y	y	**9**
	mark	o	o	o	o	o	o	o	△	△	△	o	o	o	o	o	o	**o**
	saying			inc	inc	dec	dec	dec							on			
subject 21	Remembering	s	off	inc	inc	dec	dec	don't	don't	don't	don't	s	s	s	on	y	y	**9**
	mark	o	o	o	o	o	o	x	x	x	x	o	o	o	o	o	o	**o**
	saying				inc	dec	dec								on			
subject 22	Remembering	s	off	inc	inc	dec	dec	dec	dec	dec	dec	s	s	s	on	y	y	**9**
	mark	o	o	o	o	o	o	o	△	△	△	o	o	o	o	o	o	**o**
	saying			inc	inc	dec	dec	dec	dec	dec	dec				on	y	y	
subject 23	Remembering	s	off	s	inc	dec	dec	s	dec	dec	dec	s	s	s	on	y	y	**9**
	mark	o	o	x	o	o	o	x	△	△	△	o	o	o	o	o	o	**o**
	saying				inc	dec									on	y	y	
subject 24	Remembering	s	off	inc	don't	inc	s	don't	dec	dec	dec	s	s	s	on	y	y	**9**
	mark	o	o	o	x	x	x	x	△	△	△	o	o	o	o	o	o	**o**
	saying		off		inc	dec									on	y	y	
subject 25	Remembering	s	off	inc	inc	dec	dec	don't	dec	dec	dec	s	s	s	on	y	y	**9**
	mark	o	o	o	o	o	o	x	△	△	△	o	o	o	o	o	o	**o**
	saying		off		inc	dec		dec	dec	dec	dec				on			
subject 26	Remembering	s	s	s	inc	dec	don't	dec	dec	don't	don't	s	s	s	on	y	y	**9**
	mark	o	x	x	o	o	x	o	△	x	x	o	o	o	o	o	o	**o**
	saying				inc	dec		dec							on			
subject 27	Remembering	s	off	inc	dec	dec	dec	don't	dec	dec	dec	s	s	s	on	no	no	**9**
	mark	o	o	o	x	o	o	x	△	△	△	o	o	o	o	x	x	**o**
	saying				inc	dec	dec								on			
subject 28	Remembering	s	off	s	inc	dec	dec	dec	s	s	s	s	s	s	s	don't	don't	**9**
	mark	o	o	x	o	o	o	o	x	x	x	o	o	o	x	x	x	**o**
	saying				inc 2	dec	dec	dec							on			
subject 29	Remembering	s	off	inc	inc	dec	dec	don't	don't	don't	don't	s	s	s	on	y	y	**9**
	mark	o	o	o	o	o	o	x	x	x	x	o	o	o	o	o	o	**o**
	saying		off	s	inc	dec	dec								on			
subject 30	Remembering	s	off	inc	dec	dec	dec	don't	dec	dec	dec	s	s	s	on	y	y	**14**
	mark	o	o	o	x	o	o	x	△	△	△	o	o	o	o	o	o	**x**
	saying				inc	dec	dec								on	y	y	
subject 31	Remembering	s	off	dec	inc	dec	dec	s	s	s	s	s	s	s	on	y	y	**9**
	mark	o	o	x	o	o	o	x	x	x	x	o	o	o	o	o	o	**o**
	saying				inc	dec	dec, in	dec								y	y	

5. Conclusion

As a results, human can not think like computer. If human can memorize all the information, and their thinking process is same to the CPU of computer, the results of these two experiments come out more than 99%. However the probability of finding right malfunction by humans are only 64.52% in simple experiment, and 51.61% in complex experiment.

Why is the probability so significantly different? There are several conjectures about the causes which affect this phenomena and they are related to thinking process of human and cognition. Cognition is the mental processing that includes the attention of working

memory, comprehending and producing language, calculating, reasoning, problem solving, and decision making.[2] There are many reasons why human thinking process is different with computer, but in this experiment, we suggest that the working memory is the most important factor.

Humans have limited working memory which has only seven chunks capacity.[3] These seven chunks are called magic number. If there are more than seven sequential information, people start to forget the previous information because their working memory capacity is running over. We can check how much working memory affects to the result through the simple experiment. As you can see, the most important information in order to find the right malfunction is PRT temperature. If subjects remember that PRT temperature was increased, then they could find the right malfunction clearly since it is a unique value. Let's checking subject 3 in simple experiment. He didn't find the right malfunction. He saw PRT temperature indicator at least 4 times and said PRT T is now increasing. However 3 minutes later, he forgot the information of PRT T. It is good example of working memory, and this case can be explained by its deficiency which was fully filled with another unimportant information. Then what if we neglect the effect of working memory? The total number of subjects who have incorrect memory is 7 (subject 3, 5, 6, 7, 8, 15, 25). They could find the right malfunction if the memory hadn't changed because of lack of working memory. Then the probability of find correct malfunction will be increased to 87.10% from 64.52%.

Complex experiment has similar result. In this case, eight subjects(1, 5, 8, 9, 15, 17, 18, 30) had changed the memory, and it affects to find the right malfunction. Considering it, then the probability would be (16+8)/31 = 77.42%. The original probability is 51.61%, so if humans have infinite working memory, the probability will be increased about more than 25% in complex case. Looking into both simple and complex case, we can make a conclusion that working memory affects humans' ability of estimation of the situation about 25%.

Because of the working memory, people can not catch the changes of tendency which was increased or decreased. Both the tendency of PRZ level in simple experiment and RX T_{avg} in complex experiment are changed during the experiment. Among the 31 subjects, only two subjects (subject 19, 31) detected the change of PRZ level from decreasing to increasing, but they also forgot their detection when writing the survey.

Through this experiment, we verified that evaluating application of Bayesian inference to situation awareness of Human Operators in NPPs is not accurate, and to evaluate situation awareness of human operator has to consider human cognitions.

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