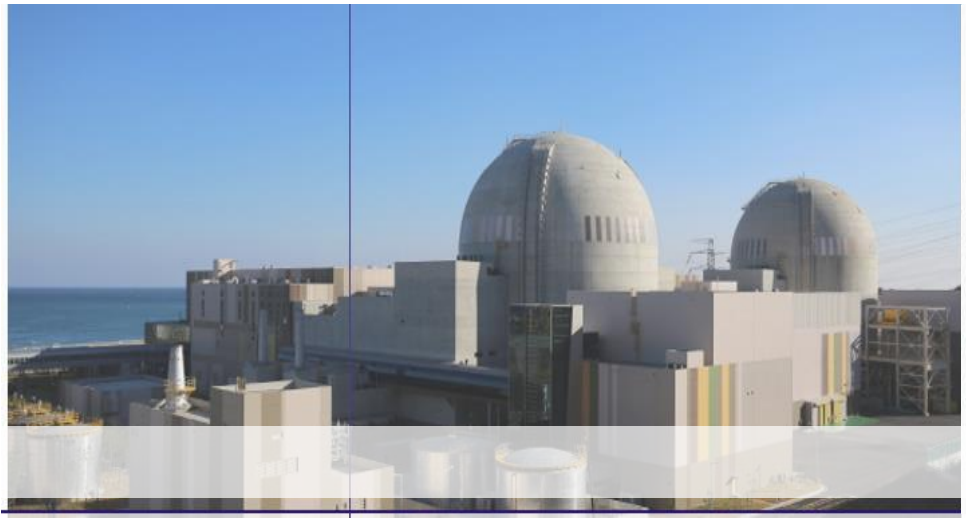

Experimental Analysis on the Relationship between Performance Shaping Factors and Human Performance In Digital MCR

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Yochan Kim, Inseok Jang (KAERI)

Contents

1. Introduction

Introduction

1. Objective

▶ Purpose of this research

- Experimental analysis on the relationship between performance shaping factors (PSFs) and operator's performance in nuclear power plants

Introduction

2. Necessity

▶ What is Performance Shaping Factor (PSF) ?

- Influencing human performance in the human reliability analysis (HRA)
- In the HRA, it is necessary to identify PSFs that are the most relevant and influential in the task analyzed
- Experience, procedure, stress, … etc.

Introduction

2. Necessity

▶ Necessity of this research

- Relying on expert judgements rather than the knowledge from actual experiments and observations
- In the case of digital MCR in APR-1400, it is expected that uncertainty of HRA will be higher than that of analog one

➢ To decrease uncertainty of HRA and assess realistic NPP risk, it is necessary to research about the effect that PSFs affect operator's error through experiments

2. Performance Shaping Factors

Performance Shaping Factors

Selected PSFs

PSFs	Description	Example
Operator's experience	• Whether the operators have operating experience and license or not	More experienced group Less experienced group
Time urgency	• Whether there are tasks which are performed urgently or not	Urgent group Less urgent group
Complexity of tasks	• How complex the task is to perform in the scenario	DBA BDBA
Procedure types	• Kinds of procedures	SPTA, DA, ORP, FRP

➢ Selected PSFs are generally used in most of HRA methodologies

Performance Shaping Factors

Procedure Types

1) SPTA (Standard Post Trip Action)

- Checking safety functions

2) DA (Diagnostic Action)

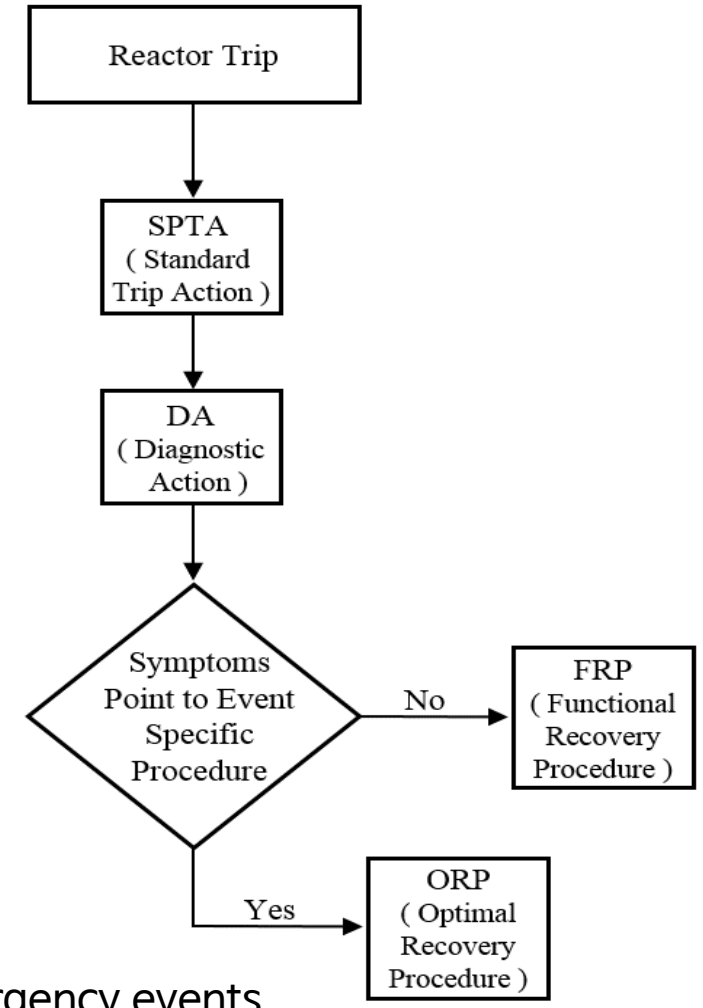
- Entering to diagnose plant status

3) ORP (Optimal Recovery Procedure)

- Event-based procedure
- When operators identify an event that can be handled

4) FRP (Functional Recovery Procedure)

- Any specific event is not diagnosed
- A combined accident of more than two emergency events
- Focusing on recovering critical safety functions



3. Human Performances

Human Performances

Human Performance

- Measurements in the experiment

Time to entering cool down from reactor trip

Averaged completion time / instruction

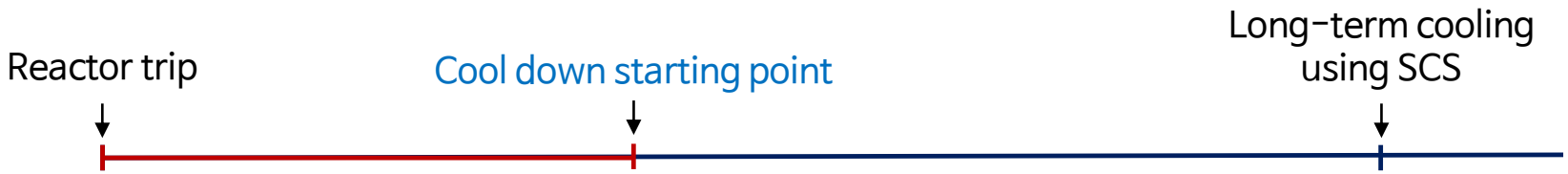
Workload (MCH)

Situation Awareness (SART)

Secondary task

Human Performances

▶ Time to entering cool down from reactor trip



※ Cool down starting point

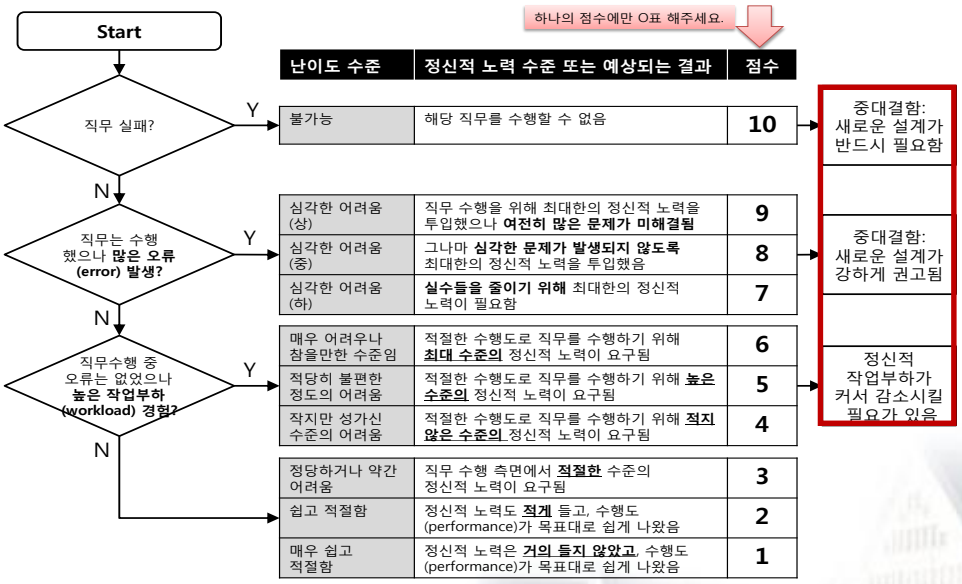
- SBCS, ADV valve open (Secondary cool down)
- POSRV valve open (Feed & Bleed operation)

▶ Averaged completion time / instruction

Human Performances

MCH (Workload) ➡ Referring about necessity of design improvement

- Estimation of psychological and physical workload during performing a scenario
- Developed by Wierwille and Casali (1983)
- Regularly used in the field of aviation such as aircraft-handling qualities
- Measured by the questionnaire below

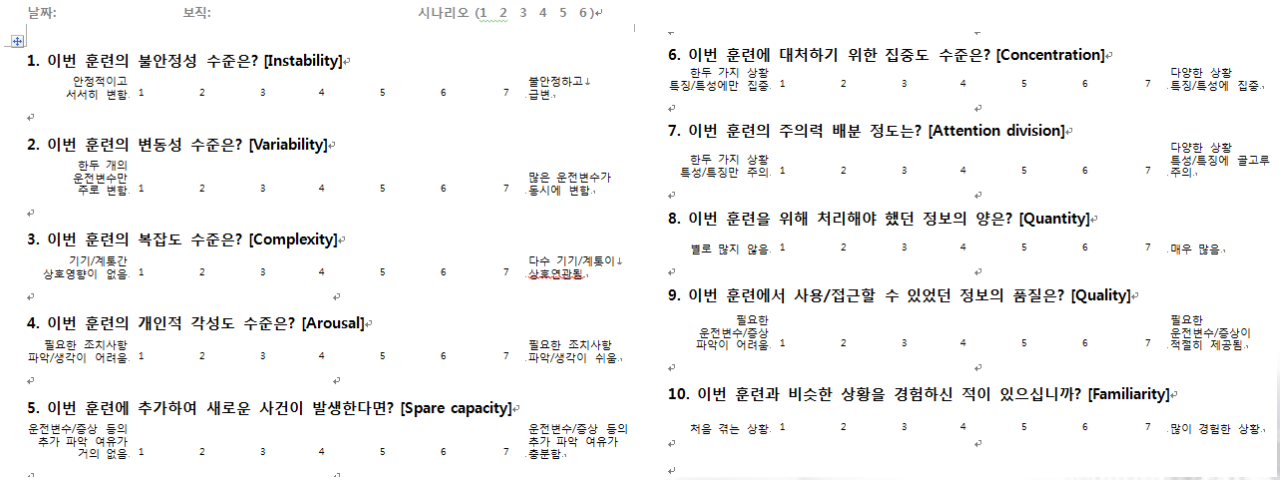


〈MCH〉

Human Performances

▶ SART (Situation awareness)

- Simplistic post-trial subjective rating technique to elicit the subjective opinion on how aware a person was during task performance
- Developed by Taylor (1990)
- Originally developed for the assessment of pilot SA
- Measured by the questionnaire below



날짜: 보직: 시나리오 (1 2 3 4 5 6)

1. 이번 훈련의 불안정성 수준은? [Instability]
안정적이고 서서히 변함 1 2 3 4 5 6 7 불안정하고 급변

2. 이번 훈련의 변동성 수준은? [Variability]
한두 개의 운전변수만 주로 변함 1 2 3 4 5 6 7 많은 운전변수가 동시에 변함

3. 이번 훈련의 복잡도 수준은? [Complexity]
기기/계통간 상호영향이 없음 1 2 3 4 5 6 7 다수 기기/계통이 상호연관됨

4. 이번 훈련의 개인적 각성도 수준은? [Arousal]
필요한 조치사항 파악/생각이 어려움 1 2 3 4 5 6 7 필요한 조치사항 파악/생각이 쉬움

5. 이번 훈련에 추가하여 새로운 사건이 발생한다면? [Spare capacity]
운전변수/증상 등의 추가 파악 여유가 거의 없음 1 2 3 4 5 6 7 운전변수/증상 등의 추가 파악 여유가 충분함

6. 이번 훈련에 대처하기 위한 집중도 수준은? [Concentration]
한두 가지 상황 특징/특성에만 집중 1 2 3 4 5 6 7 다양한 상황 특징/특성에 집중

7. 이번 훈련의 주의력 배분 정도는? [Attention division]
한두 가지 상황 특성/특징만 주의 1 2 3 4 5 6 7 다양한 상황 특성/특징에 골고루 주의

8. 이번 훈련을 위해 처리해야 했던 정보의 양은? [Quantity]
별로 많지 않음 1 2 3 4 5 6 7 매우 많음

9. 이번 훈련에서 사용/접근할 수 있었던 정보의 품질은? [Quality]
필요한 운전변수/증상 파악이 어려움 1 2 3 4 5 6 7 필요한 운전변수/증상이 적절히 제공됨

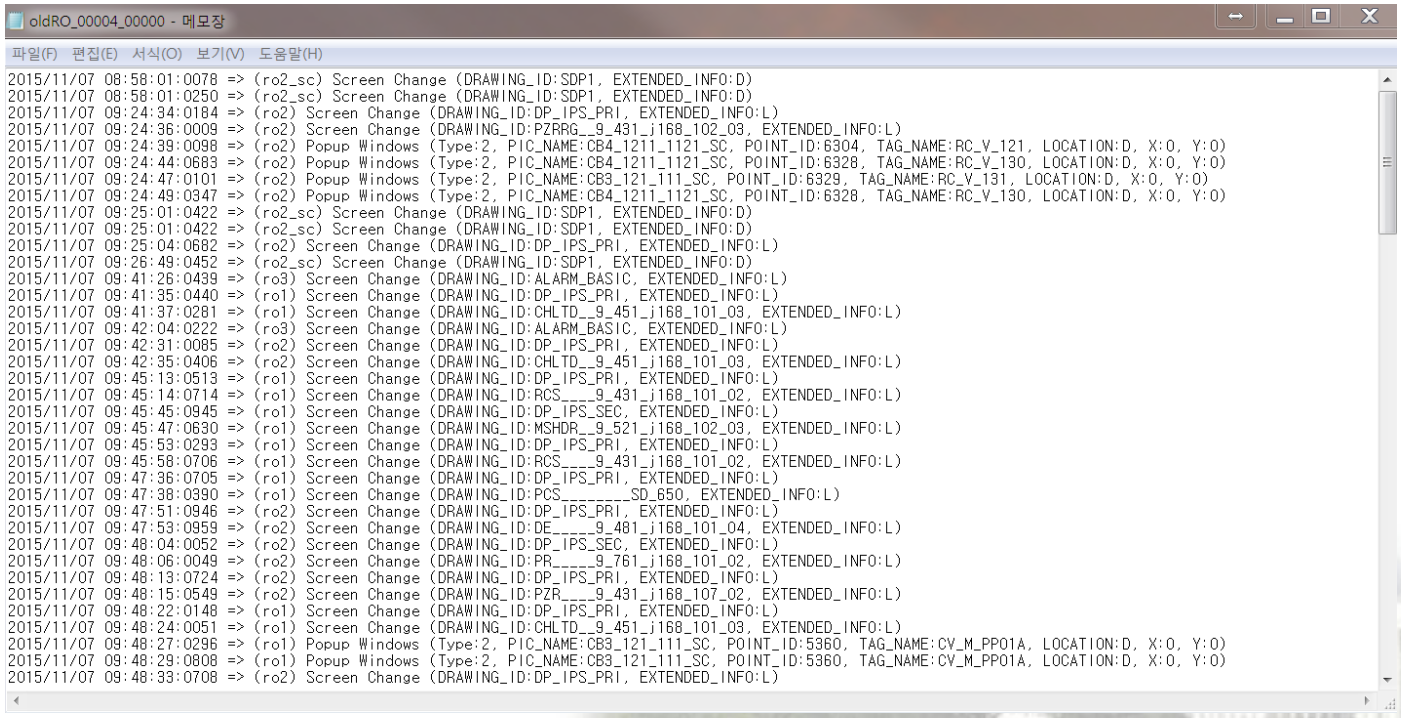
10. 이번 훈련과 비슷한 상황을 경험하신 적이 있으십니까? [Familiarity]
처음 겪는 상황 1 2 3 4 5 6 7 많이 경험한 상황

〈SART〉

Human Performances

Secondary task

- Tasks that operator performs such as set-up change and navigation during scenarios
- Characteristics of digitalized MCR
- Measured by simulator log data below



Human Performances

Human Performance

- Measurements in the experiment

Time to entering cool down from reactor trip

Averaged completion time / instruction

Workload (MCH)

Situation Awareness (SART)

Secondary task

4. Experiment design

Experiment design

1. Randomized factorial experiment

▶ Experiment design ①

Time urgency	Complexity of tasks	Operator's experience			
		More experienced		Less experienced	
Urgent	Scenario 1 (DBA)				
	Scenario 2 (DBA + Masking)				
	Scenario 3 (BDBA)				
Less Urgent	Scenario 4 (DBA)				
	Scenario 5 (DBA + Masking)				
	Scenario 6 (BDBA)				

Experiment design

1. Randomized factorial experiment

▶ Experiment design ②

	Operator's experience			
Procedure types	More Experienced		Less Experienced	
SPTA				
DA				
ORP				
FRP				

Experiment design

2. Scenario

▶ Six scenarios

Time urgency	Complexity of tasks	No.	Scenario
Urgency (=30min)	DBA	1	LOOP + ADV Open
	DBA + Masking	2	SGTR + N16 Failure
	BDBA	3	LOCA + SI Failure
Less Urgency (〉30min)	DBA	4	SBLOCA (Interface system LOCA)
	DBA + Masking	5	ESDE + N16 Failure
	BDBA	6	LOAF

※ N16 Failure (Masking) : It makes hard to distinguish between LOCA and SGTR

Experiment design

3. Participants

▶ Groups according to operator's experience

Groups	Team number	Description
More Experienced	Team 1	Operators who have operating license of APR-1400
	Team 2	
Less Experienced	Team 3	Operators who have operating license but, other types of reactors
	Team 4	

- Before the experiment was performed, the operators had one-day training session to be familiar with digital MCR

Experiment design

4. Simulator

▶ KINGS simulator

- Fully digitalized MCR in APR-1400

▶ Difference between KINGS simulator and APR-1400

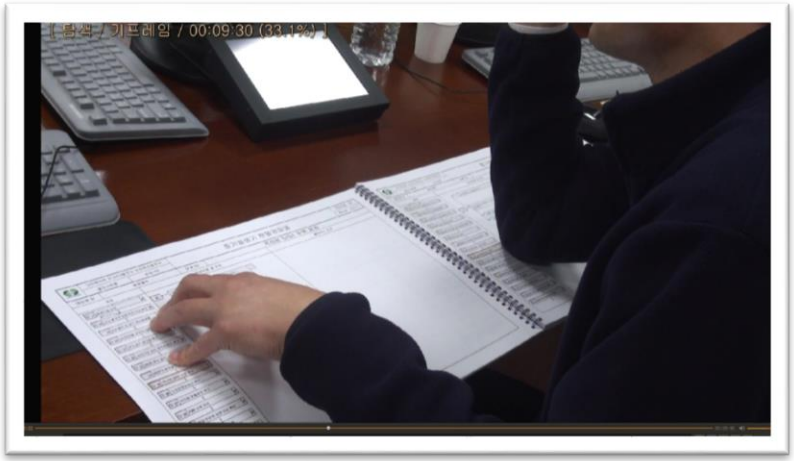
- Using paper based procedure (CPS is hard to learn)
- Operated by three actual operators (SRO, RO, TO/EO)
- Each operator has three screens for control and monitoring
- Size of LDP is smaller than actual LDP

Experiment design

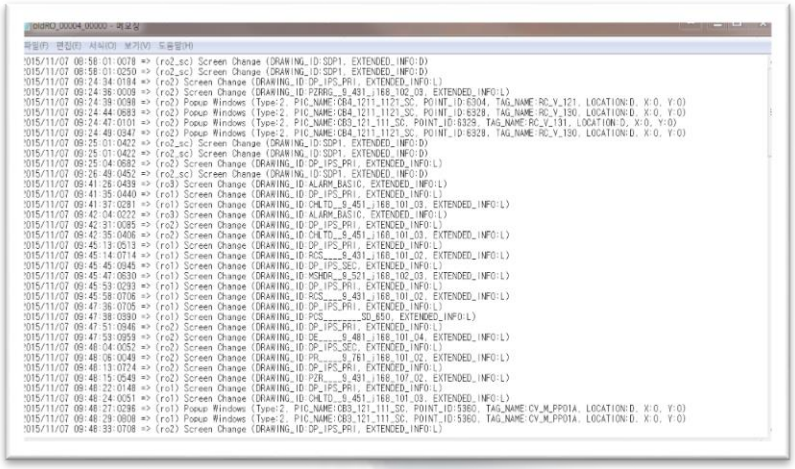
5. Performance measure

▶ Data collection

- Audio / Video recording : conversation / primary task analysis
- Simulator log data : error / primary task / secondary task analysis
- Observers : error analysis



〈Audio / Video recording〉



〈Simulator log data〉

5. Results

Results

1. Experiment design ①

▶ Time to entering cool down from reactor trip

PSFs	P-value	Description
Operator's experience	P < 0.01	• The time by the more experienced group is statistically shorter than that by the less experienced group
Time urgency	P > 0.05	• There is no statistical difference
Complexity	P > 0.05	
Interaction	P > 0.05	• There is no statistical difference

▶ Averaged completion time / instruction

PSFs	P-value	Description
Operator's experience	P < 0.01	• The time by the more experienced group is statistically shorter than that by the less experienced group
Time urgency	P > 0.05	• There is no statistical difference
Complexity	P > 0.05	
Interaction	P > 0.05	• There is no statistical difference

● Results

2. Experiment design ②

▶ Averaged completion time / instruction

PSFs	P-value	Description
Operator's experience	P < 0.01	• The time by the more experienced group is statistically shorter than that by the less experienced group
Procedure types	P < 0.01	• There is statistical difference among the procedure types
Interaction	P < 0.01	• There is statistical difference both operator's experience and procedure types

※ Procedure types

- SPTA DA ORP FRP ⟶ SPTA ≠ DA, DA ≠ ORP, OPR ≠ FRP, or SPTA ≠ FRP

▶ The result of Tukey's test about procedure types

Results

2. Experiment design ②

▶ Averaged completion time / instruction

PSFs	P-value	Description
Operator's experience	P < 0.01	• The time by the more experienced group is statistically shorter than that by the less experienced group
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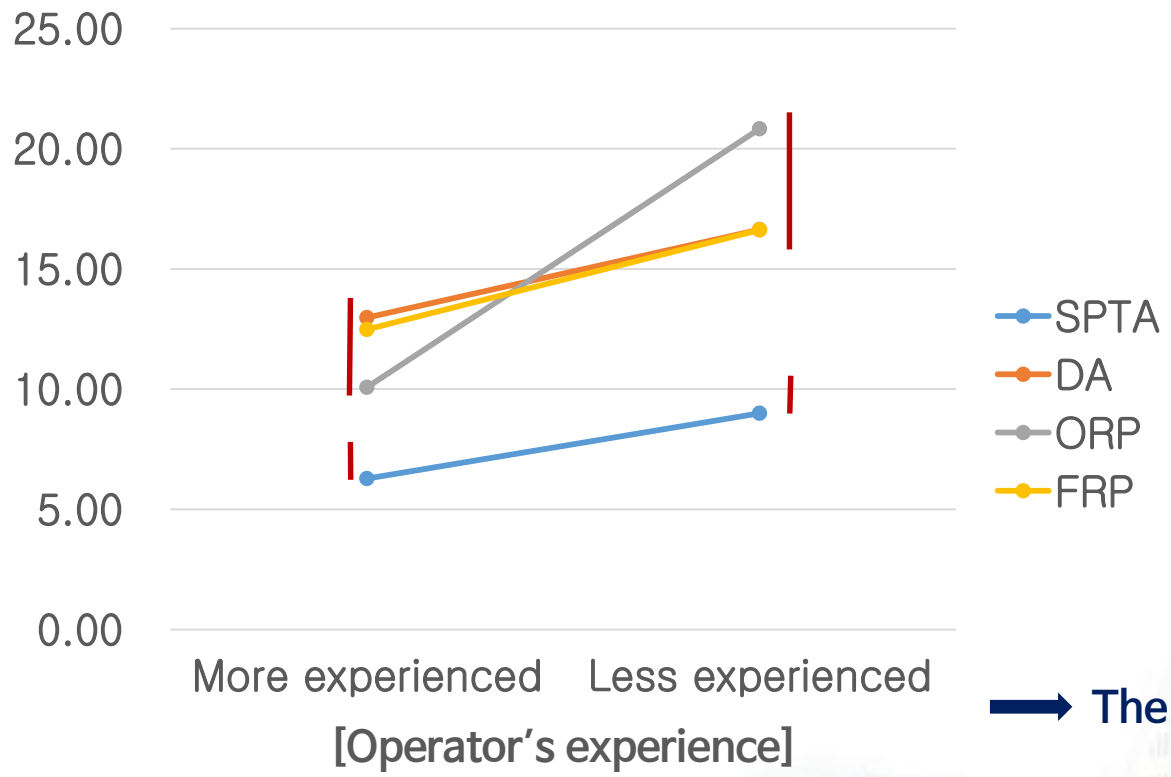
● Results

2. Experiment design ②

▶ Averaged completion time / instruction



➡ The interaction effects

6. Summary & Conclusion

Summary & Conclusion

Summary

- This study conducted an experiment to investigate the relationship between PSFs and Human Performance
- Actual operators and NPP simulator are applied in this experiment
- Averaged completion time / instruction statistically differed depending on the procedure types and operator's experience
- Time to entering cool down from reactor trip statistically differed depending on the operator's experience
- There is no statistical difference in time urgency(30 min) and complexity

Summary & Conclusion

Summary

- Time urgency : averaged completion time / instruction

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
X1	1308.34	1	1308.34	7.37	0.0188
X2	571.18	1	571.18	3.22	0.0981
X1*X2	465.88	1	465.88	2.62	0.1312
Error	2130.21	12	177.52		
Total	4026.06	15			

- The result of ANOVA test between Operator's experience(X1) and time urgency(X2)
- DBA and DBA+Masking
- There is almost statistical difference in time urgency

Future plan

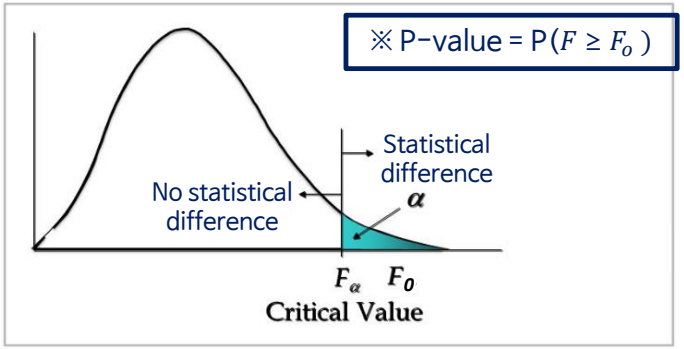
- We are going to analyze the relationship between selected PSFs and other human performance such as MCH, SART and secondary tasks

Q & A

▶ Data analysis

- ANOVA test

  - A collection of statistical model used to analyze the differences among group means and their associated procedures (such as "variation" among and between groups)



〈 F distribution 〉

Ex) Operator's experience (X1) and Time urgency (X2)

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
X1	6822400,67	1	6822400,7	27,88	0
X2	1441,5	1	1441,5	0,01	0,9396
X1*X2	7072,67	1	7072,7	0,03	0,8667
Error	4894065,67	20	244703,3		
Total	11724980,5	23			

〈 A result of ANOVA test 〉

▶ Data analysis

- Tukey's test
  - A single-step multiple comparison procedure and statistical test
  - To find means that are significantly different from each other

Ex) Procedure types,

SPTA DA ORP FRP

Source	SS	df	MS	F	Prob>F
Groups	900.29	3	300.097	11.59	2.76563e-06
Error	1863.84	72	25.887		
Total	2764.14	75			

〈A result of ANOVA test about procedure types〉

SPTA ≠ DA, DA ≠ ORP, OPR ≠ FRP, or SPTA ≠ FRP

➢ The result of Tukey's test