Nuclear Engineering and Technology 52 (2020) 78–86

Contents lists available at ScienceDirect

Nuclear Engineering and Technology

journal homepage: www.elsevier.com/locate/net

Original Article

Study on cognitive load of OM interface and eye movement experiment for nuclear power system

Jingling Zhang [a,*], Daizhong Su [b], Yan Zhuang [a], Furong QIU [a]

[a] College of Mechanical and Electrical Engineering, Harbin Engineering University, Harbin, China
[b] Advanced Design and Manufacturing Engineering Centre, School of Architecture, Design and the Built Environment, Nottingham Trent University, UK

ARTICLE INFO

Article history:
Received 10 March 2019
Received in revised form
16 June 2019
Accepted 21 June 2019
Available online 26 June 2019

Keywords:
Operation and monitoring interface
Cognitive load
Nuclear power system
Eye movement data

ABSTRACT

The operation and monitoring (OM) interface is the digital medium between nuclear power system and operators. The cognitive load of OM interface has an important effect on the operation errors made by operator during OM task between operator and computer. The cognitive load model of OM interface is constructed for analysing the composition and influencing factors of OM interface cognitive load. And to study the coping strategies and methods for cognitive load of nuclear power system. An experiment method based on eye movement is proposed to measure the cognitive load of OM interface. Experiment case is carried out with 20 subjects and typical OM interface of a nuclear power system simulator. The OM interface is optimized based on the experiment results. And the results comparison between the original OM interface and the optimized OM interface shows that the cognitive load model and proposed method is valuable contributions in reducing the cognitive load and improving the interaction efficiency of OM tasks.

1. Introduction

Computer based digital operation and monitoring (OM) interface has been the most important medium between operators and advanced nuclear power system. The information in OM interface is related to the processing procedure of nuclear power system. The amount of dynamic and static information monitored in OM interface is large, and the coupling relationships among them are complicated. In the main control room of a nuclear power system, the OM tasks based on digital OM interface include observation, operation and information processing, which occupy a large amount of cognitive resources. Operation errors with OM interface may cause great dangers for nuclear power system. The cognitive load cannot exceed the operator's affordable load limit, for exceeding the limit could lead to high psychological stresses, high probability of operation errors and low efficiency [1]. Therefore, it is necessary to study the cognitive load of OM interface for nuclear power system, and to ensure that the cognitive load of OM interface properly matches operator's capacity.

Cognitive load is important in interaction design for efficiency and safety operation of human-computer interaction, and it is received more and more attention [2]. In the past, task load index (TLX), subjective workload assessment technique (SWAT) and work load profile (WP) scale technologies have been frequently used to measure the cognitive load of OM interface in nuclear power plants from psychology, physical strength, time, performance, frustration, and operation resource requirements, by subjective scale scoring to measure cognitive load. For example, Park et al. used the TLX scale to study the cognitive load of emergency tasks in nuclear power control room, with considering psychological needs, physical needs, time demands, effort levels, performance levels, and frustration levels [3]. Recently, eye movement data have been used more and more in cognitive load of human-computer interaction design. The eye movement data were used to examine the relationship between visual attention and stated preferences, were used to analyse cognitive load of web sites [4,5]. The eye movement measurement was used in vehicle driving interaction load [6,7], was applied to evaluate the product design elements [8], and was used to analyse cognitive load of accident diagnosis [9]. The eye movement data are more and more applied to study cognitive load on mobile terminals [10], and aircraft cockpit [11]. Eye movement data are directly related to operation process with OM interface, and eye movement measurement is objective and real-time to analyse cognitive load of OM interface. For example, the eye

* Corresponding author.
E-mail addresses: Zhangjinglinghrb@126.com (J. Zhang), daizhong.su@ntu.ac.uk (D. Su), zhuangyan@hrbeu.edu.cn (Y. Zhuang), qq420521314@163.com (F. QIU).

https://doi.org/10.1016/j.net.2019.06.023
1738-5733/

movement data was used to infer operator's thoughts in nuclear power plants [12]. As an effective means, the eye movement method has been applied in OM interface in various research field, but its application in nuclear power system is still need more study.

The OM interface is complex, facing with the challenge of high cognitive load and significant impact of operation errors. The cognitive load and measurement method of OM interface are important issues for effective and safety operation of nuclear power system. The measurement method of OM interface and the method of using objective data to analyse cognitive load needs to be studied. In this study, the cognitive load model and eye movement experiment method are proposed, which have been applied to improve OM interface design of nuclear power system. The cognitive load model of OM interface for nuclear power system is presented firstly. And then, the eye movement experiment method is proposed. The experiment case is conducted, including the experiments on both the original and optimized OM interface. The experiment results prove the availability and effectiveness of the proposed method.

2. Cognitive load of OM interface for nuclear power system

2.1. Cognitive load of OM interface

The OM interface of advanced nuclear power plants commonly uses the mimic displays to describe the whole or partial nuclear power system, and uses the overview map, trends map, bar charts, and function charts to describe system flow, equipment status, operation parameters and gauges. The display formats contain continuous text displays, mimics, tables and lists, graphs, and so on. The features of OM interface design include: (1)display pages design: display elements and forms, screen layout, mimic displays, critical parameters and variables; (2)OM interaction design: menu navigation, information input and feedback, managing displays; (3) OM-related system properties: system performance, user assistance, and error detection and correction. Fig. 1 shows an example of digital OM system of a nuclear power station, and digital OM interface example of a nuclear power system simulator. The simulator is used in OM interface design and verification, and nuclear power operation education, which include large screen, digital consoles and simulation process system.

2.2. Cognitive load model of OM interface

Cognitive load is the sum of cognitive resources, such as perception, memory, thinking, knowledge and experience, which are necessary for implementing the operation process with OM interface for successful completion of specific tasks [13]. The cognitive load of OM interface for nuclear power system is established based on the cognitive resource limitation theory and schema theory [14]. The knowledge representation and storage are used to organize cognitive load. Based on schema theory, according to different cognitive resources of cognitive load demand, cognitive load can be combined by several parts in a certain way. The components of cognitive load are called variables, which contain the necessary characteristics of cognitive load. And different components are used to describe the cognitive load of OM interface. Operator's cognitive resource is limited, and if the required cognitive resources exceed operator's cognitive resource capacity, it then causes cognitive overload. According to the schema theory, knowledge about operation of nuclear power system that operator acquiring from the learning and accumulating of experiences is never disordered and unsystematic in brain, or form a knowledge unit around a specific theme for storage. Both the knowledge representation and storage method are called schema. A schema is stored in operator's long term memory, with mass of information, integrated information elements and generated rules, and is used to dispose and process automation mechanism, to meet the need for cognition. And the cognitive load model of OM interface for nuclear power system is constructed, as shown in Fig. 2.

The cognitive load model of OM interface is useful to study the components, influence factors and coping strategies of cognitive load. The affected factors include operator's prior knowledge and experience, and complexity of OM interface. Within the proposed model, the total cognitive load is integrated from intrinsic cognitive load, extraneous cognitive load and germane cognitive load, with the following features: (1) The intrinsic cognitive load consists of many elements which are processed and integrated into schema in operator's working memory. It is mainly affected by internal factors so called internal intrinsic cognitive load, and external factors so called extrinsic intrinsic cognitive load. The internal factors are affected by operator's knowledge and experience, while the external factors are determined by the complexity of OM interface. (2) The extraneous cognitive load is caused by cognitive activities that do not contribute to the task, which is non-effective cognitive load. It depends on the operator's schema availability. (3) The germane cognitive load is that the operator uses residual cognitive resources for the next cognitive processing, usually cognitive processing of OM interface information can be promoted.

The cognitive load is indirectly related to the operator's performance and efficiency during OM tasks [15]. The cognitive load can be analysed comprehensively with the operator's performance and physiological state during OM tasks. The cognitive load model reveals the sources which affect the operator's cognitive load, therefore, solutions can be found to reduce the cognitive loads based on the sources indicated by the model. It is aimed to reduce

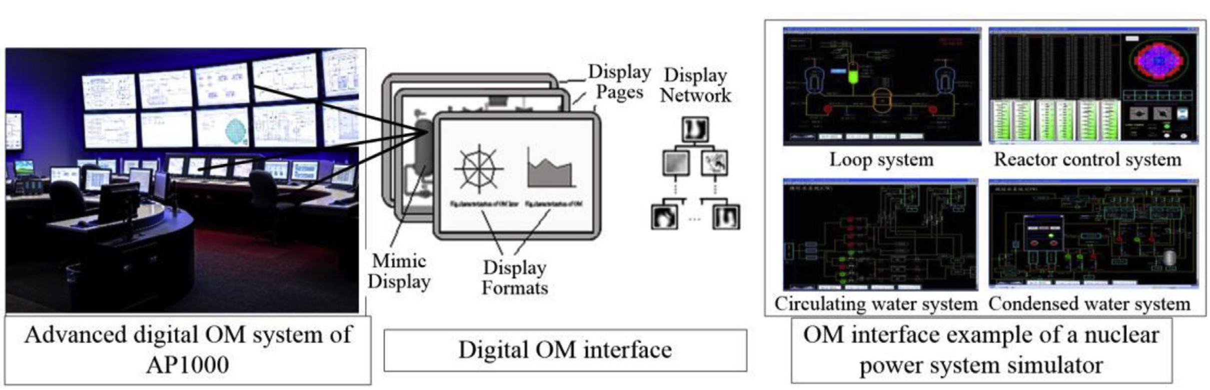


Fig. 1. The advanced digital OM system example and OM interface example of a nuclear power system simulator.

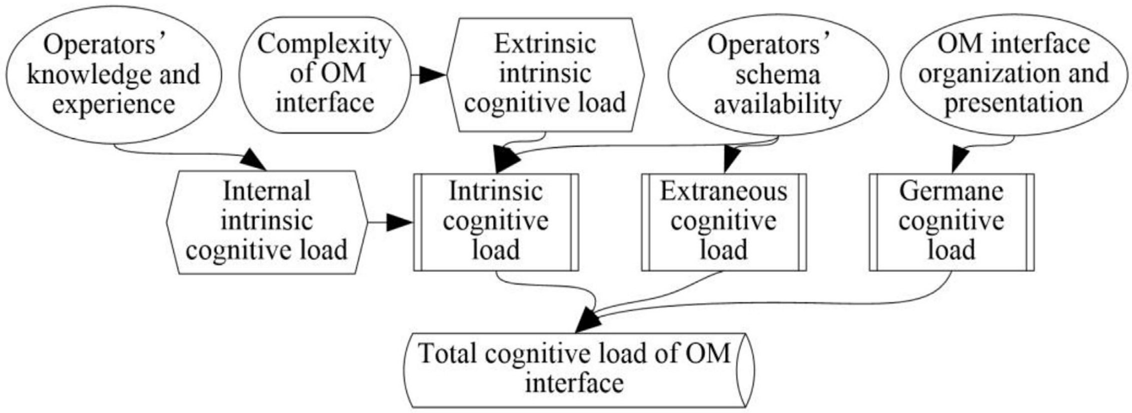


Fig. 2. Cognitive load model of OM interface.

the operator's cognitive load by reducing the complexity of OM interface. The external intrinsic cognitive load is an external source affecting the intrinsic cognitive load. Based on the cognitive load model of OM interface, the composition and influencing factors of cognitive load can be clearly defined, and coping strategies can be formulated. By measuring the cognitive load, the magnitude of cognitive load and the impact points of OM interface can be determined, and OM interface can be optimized.

3. Experiment method of OM interface cognitive load

3.1. Eye movement patterns of OM interface

The OM interface is mainly used for information display through visual interface. Therefore, the eye movement measurement method is proposed to measure cognitive load of OM interface. After the occurrence of a stimulation or event, OM interface of a nuclear power system directly causes the eye feature changes. Operator's eye movement behaviors of OM interface are divided into two phases [16]: (1)Preparation phase, with the start of the saccade with OM interface presentation, OM interface target quickly leads the eye sight to jump to the target position; (2)Search phase, which is confirmed after the search to the target stimulus. The preparation phase and search phase are the core processes of eye movement of OM interface.

Saccade is a mainly visual task of OM interface, which consists of fixation and saccade behavior patterns [17]: (1) Fixation is that the foveal vision aims at the target on OM interface for a brief stop, and the eye sight stops at the target briefly and quickly jump between targets. The fixation time depends on the difficulty of extracting information from OM interface. (2) Saccade is attention shift, and the sight fast hops between fixation points on OM interface. Therefore, it can locate to the new fixation point. Saccade duration is short, lasting for 30–120 m s, and usually it cannot acquire any meaningful information from OM interface. The eye movement data model of OM interface for nuclear power system includes:

(1) Eye movement trace diagram. It is real-time superimposition of shift position between fixation points on OM interface, including sequence information of fixations, fixation point time and distance information, with the advantages of intuitive and comprehensive description of the eye movement characteristics of OM interface.
(2) Eye movement data. It refers to temporal data, distance data and derived data of eye movement [18]. Temporal data include saccade path time, saccade time, fixation time, and interest residence time. The fixation time and saccade time refers to the behavior of eye movement on the fixation point and stay for the time using the search point of gaze. The time of scanning path is the sum of saccade time and fixation time. Distance data includes length of saccade path and saccade amplitude. Saccade amplitude refers to the distance between continuous fixation point, and the mean saccade amplitude as the evaluation of sight can directly reach the target distance. The scanning path length is the sum of the distances between each fixation point. The longer the path is, the lower the cognitive efficiency is. Derived data refers to the ratio of time and distance data processing.

3.2. Experiment procedure of OM interface cognitive load evaluation

The experiment procedure of OM interface for nuclear power system is shown in Fig. 3, which include the following steps:

(1) Preparation of the experiment: *N* subjects are selected to participate in the experiment, and then a typical OM interface and tasks are selected. The subjects have nuclear power relevant knowledge, and have a certain degree of understanding of OM interface and tasks. And before the experiment, the subjects have been fully explained with the tasks, contents and requirements of experiment.
(2) Experiment equipment selection and set-up: SMI HED eye movement tracking system is selected as the experiment equipment to track subjects' eye movement, including head-mounted eye tracker, video capture iViewX software and eye movement data analysis BeGaze software. The sampling frequency is 50 Hz.
(3) Experiment implementation: subject i ($i = 1 \ldots .N$) follows the typical task steps to process the information cognition process presented on OM interface, soft control operation, eye movement tracker real-time tracing, record subjects' eye movement process; record all eye movement data, until the *Nth* subject finish recording experiment ends. Interview the subjects about the problems and errors, record reasons, analysis the usability of subjects' eye movement data.
(4) Experiment data analysis: statistics and analysis are performed on the variation of the dependent variables based on the experiment conditions with the descriptive statistical method. Use an arithmetic means to describe eye movement data sample position feature; eye movement data dispersion

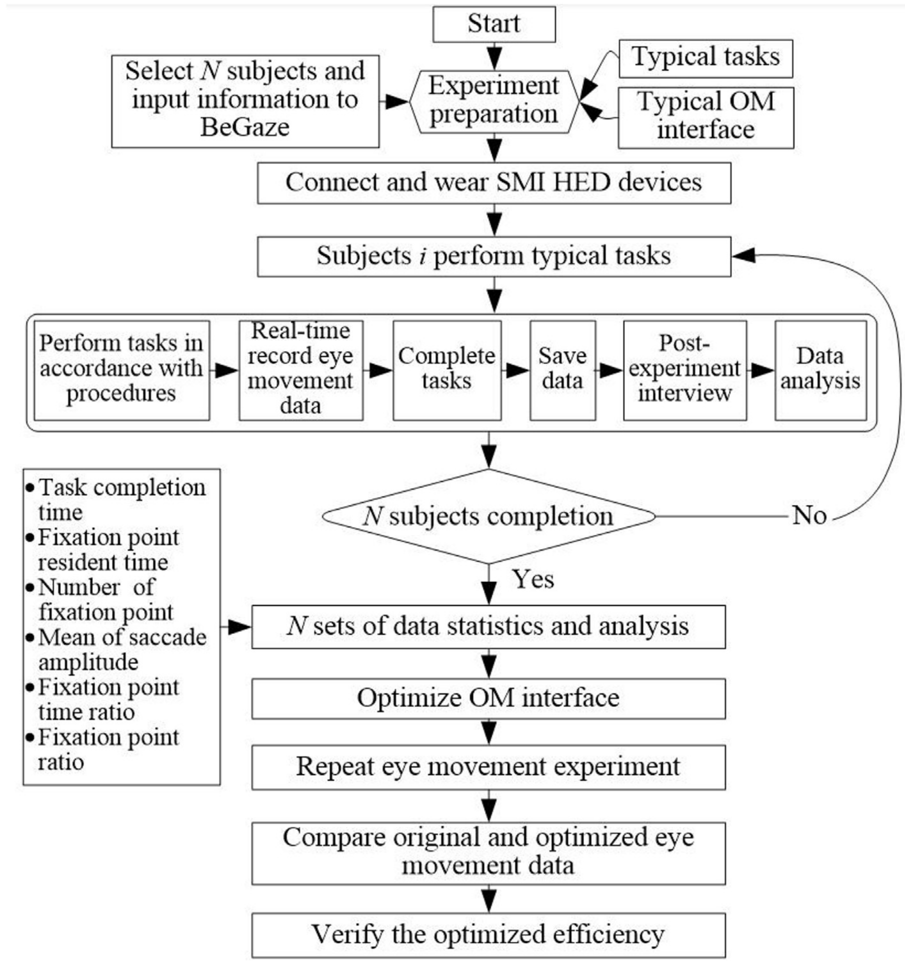


Fig. 3. Eye movement experiment procedure of OM interface.

is expressed as standard deviation. Statistics and analysis of experiment data are conducted including the task time, fixation time, the number of fixation point, and mean of saccade amplitude.

(5) Analysis and optimization: according to experiment results, analysis is conducted to find out the relation between OM interface and operator's attention distribution. And then, OM interface is optimized based on the analysis result.

(6) The eye movement analysis experiment is performed repeatedly on the optimized OM interface, and the eye movement data of the original and optimized OM interface are compared to verify the effectiveness of the optimization.

4. Experiment case

4.1. Experiment set-up

According to the subjects selection principle [19], 20 subjects (12 males and 8 females) are selected, who are researchers on OM interface and postgraduate between 22 and 34 years old. The OM interface is displayed on 19 inch liquid crystal display (LCD). Experiment scene of a nuclear power system simulator is shown in Fig. 4. The sub-systems of OM interface used in the experiment include deaerator system (DEA), auxiliary steam system (AS), cold fresh water system (CFW), gasoline engine extraction system (TE), and main feed water system (MFW). The OM task procedure is conducted within 18 steps, such as: step 1: select the main menu, in the CFW OM interface; step 2: in the main menu, choose reactor operation and monitor, and then confirm reactor control rod in the specified adjustment; step 3: return to the main menu, and within the TE OM interface, set 195 MW; …; step 16: shut down CQ202V; step 17: shut down CQ302V; step 18: return to the main menu, choose TE system, select steam turbine drain valve CQ510SV, and then confirm.

4.2. Experiment of the original and optimized OM interface

Following the proposed method, the experiment work is carried out on the original OM interface. Fig. 5 shows samples of eye movement hotspot diagram, saccade path diagram of CFW OM interface, which are acquired from the experiment.

The SMI HED system records the original data of time, eye position, speed and pupil changes during OM task. The initial data are analysed by statistical methods such as maximum, minimum, mean, sum, ratio and variance, to acquire the statistical number of fixation point, number of saccades, saccade distance, task time and other relevant data, which are shown in follow tables. The statistical total number of eye-focusing points on the original OM interface for typical tasks is shown in Table 1. The statistical saccade number of original OM interface is shown in Table 2. The statistical saccade distance of original OM interface is shown in Table 3. The statistical total time and operation errors of original OM interface is shown in Table 4. The statistical saccade velocity and acceleration of original OM interface is shown in Table 5.

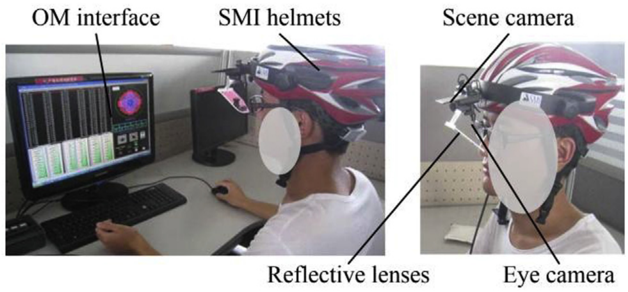


Fig. 4. Experiment scene for OM interface of a nuclear power system simulator.

The eye movement data reflect the subjects' performance while the OM task is carried out with the OM interface. The total number of eye-focusing points can be used to judge whether the subjects have to observe and search information frequently on OM interface in order to acquire enough information. The subjects' saccade distance can be used to judge the efficiency of information searching of OM interface. The statistical total time can be used to judge the efficiency for typical tasks. The operation errors can be used to judge the subjects' performance for typical tasks.

The results shown in Tables 1–5 reveal the following: (1) The longer time OM interface task spent, the more difficult subjects cognized and extracted information from OM interface. The time spent on searching information and operation in OM interface is related to the difficulty of task completion. The more time the subjects spend on information search, and with more errors, the more difficult it is to complete the OM task. (2) The longer the fixation time, the more time spend on extracting the display information. The excellent OM interface design allows subjects to

(1) eye movement hotspot diagram (2) saccade path diagram

Fig. 5. Eye movement diagram example of CFW OM interface.

Table 1
The statistical total number of eye-focusing points on original OM interface.

Total number of points on OM interface	20 subjects of experiment									
	1	2	3	4	5	6	7	8	9	10
OM interface 1	14	13	16	14	14	20	16	20	15	12
OM interface 2	69	41	40	58	47	60	58	62	56	72
OM interface 3	81	34	25	40	38	44	42	48	27	60
OM interface 4	78	82	65	79	75	105	98	114	77	108
OM interface 5	10	18	11	12	11	21	16	19	9	11
	11	12	13	14	15	16	17	18	19	20
OM interface 1	18	15	12	17	16	14	13	16	18	17
OM interface 2	42	48	36	54	47	50	53	60	46	44
OM interface 3	21	29	25	28	26	31	22	30	40	35
OM interface 4	93	100	73	85	78	83	89	87	82	96
OM interface 5	13	11	10	12	8	10	12	9	11	14

Table 2
The statistical saccade numbers on original OM interface.

Saccade numbers on OM interface	20 subjects of experiment									
	1	2	3	4	5	6	7	8	9	10
OM interface 1	15	14	17	15	15	21	17	21	16	13
OM interface 2	70	42	41	59	48	61	59	63	57	73
OM interface 3	82	35	26	41	39	45	43	49	28	61
OM interface 4	79	83	66	80	76	106	99	115	78	109
OM interface 5	11	19	12	13	12	22	17	20	10	12
	11	12	13	14	15	16	17	18	19	20
OM interface 1	19	16	13	18	17	15	14	17	19	18
OM interface 2	43	49	37	55	48	51	54	61	47	45
OM interface 3	22	30	26	29	27	32	23	31	41	36
OM interface 4	94	101	74	86	79	84	90	88	83	97
OM interface 5	14	12	11	13	9	11	13	10	12	15

Table 3
The statistical saccade distance of original OM interface (unit:pixel).

Saccade distance	20 subjects of experiment									
	1	2	3	4	5	6	7	8	9	10
Minimum	0.3	0.5	0.7	0.3	0.2	0.5	0.2	0.1	0.5	0.6
Maximum	1622.7	430	593.1	848.5	607.4	675.5	655.8	612	621.1	360.1
Mean	122.1	69.5	82.1	72.9	63.5	136.8	80.7	65.72	61.3	62.8
	11	12	13	14	15	16	17	18	19	20
Minimum	0.5	0.2	0.1	0.4	0.7	0.1	0.4	0.2	0.5	0.5
Maximum	717.6	1018.3	1244.9	399.4	325.5	1650.2	244.1	478.4	1178.6	533.3
Mean	74.3	86.6	79	100.6	74	177.5	56.2	68	86.9	79

Table 4
The statistical total time and operation errors of original OM interface.

Time and errors	20 subjects of experiment									
	1	2	3	4	5	6	7	8	9	10
Total time(s)	343.7	219.0	222	300	285.6	278.6	269.3	283.9	216.1	280.8
Operation errors	4	2	0	1	3	0	0	1	3	2
	11	12	13	14	15	16	17	18	19	20
Total time(s)	212.8	207.1	208.1	222.4	213.9	220.5	215.5	209	206	210.2
Operation errors	0	0	0	0	1	0	0	2	1	1

quickly locate important information by eye. Instead of too much information searching on OM interface. The number of fixation points reflect the cognitive performance. Usually, the more the number of the fixation, the more meaningless fixation, and the lower cognitive performance. (3) The higher the mean of saccade amplitude, the less the fixation and path for cognition. Base on the results of the original OM interface experiment, OM interface is optimized with the page layout, parameter display size, icon size, location, shape and background. The optimization ensures that the interface layout structure is matched with the task type, the differences between subsections are easily recognised, important display areas are highlights, OM interface layout with similar functions is consistent, and the layout structure is neat and standard for all OM interface. Further information about the optimization can be found in literature [20]. The optimized OM interface is shown in Fig. 6.

The hotspots, saccade path diagram obtained from the experiments of the original OM interface and the optimized OM interface are compared below as example: (1) Comparison of the hotspots. The hotspots are created based on the absolute fixation duration of the fixation point, with a maximum value of 2.2 s, which is the crimson region shown in Fig. 5(1) and Fig. 7(1) which indicate the subjects' visual browsing behavior of the original OM interface and optimized OM interface. The decrease of hotspot area and the increase of distribution area of the optimized hotspot diagram shows that the cognitive load is reduced, the understanding degree is optimized, and the ability to acquire information is increased. (2) Comparison of the saccade path diagram. Comparing Fig. 5(2) with Fig. 7(2), it can be found that the length of saccade distance of optimized OM interface is shorter than the original OM interface, which proves that enough information can be acquired without frequent observation and searching on the optimized OM interface, and the efficiency is improved.

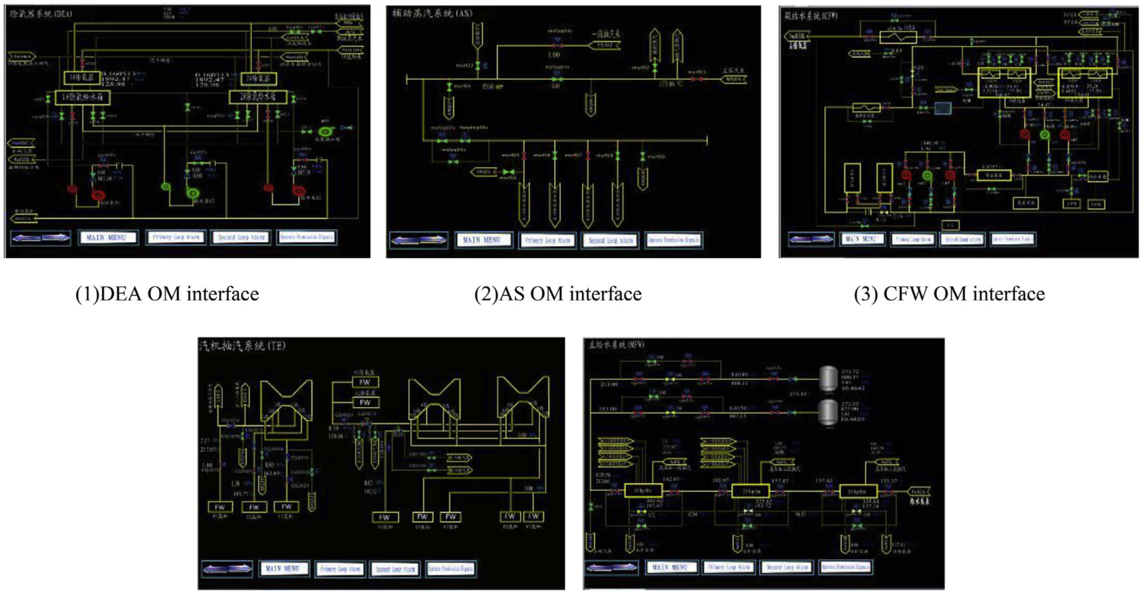
The experiment is conducted with the proposed method. Partial statistical eye movement data of the optimized OM interface are shown in follow tables as an example. Table 6 shows the statistical saccade distance example of optimized OM interface. Table 7 shows the statistical saccade velocity and acceleration of optimized OM interface.

The results comparison between the original OM interface and optimized OM interface is shown in Fig. 8.

(1) Comparison of total operation time of 20 subjects is shown in Fig. 8 (1). It can be found that the total operation time of the optimized OM interface for most subjects is less than that the original OM interface. There are 19 subjects have spent less time on the optimized OM interface in 20 subjects. The mean for 20 subjects of total operation time for the original OM interface is 241.2s, and the mean for 20 subjects of total operation time for the optimized OM interface is 201.3s. It indicates that the optimized OM interface has instantaneous visibility and visual attractiveness. The complexity, colour and form of the optimized interface are better than those of the original OM interface.

Table 5
The statistical saccade velocity and acceleration of original OM interface.

Velocity and Acceleration	20 subjects of experiment						
	1	2	3	4	5	6	7
Velocity (°/s)	247.4	78.6	235	306.4	169.3	350.9	377.5
Acceleration (°/s^2)	7426.9	3697.8	7502.1	11644.3	5681.6	10574.5	11956.5
	8	9	10	11	12	13	14
Velocity (°/s)	307.4	171.6	85.1	318.4	488.3	215.6	515.3
Acceleration (°/s^2)	9346.7	5504.5	3974.9	9889.5	21260.4	7808.9	15163.8
	15	16	17	18	19	20	
Velocity (°/s)	248.3	487	556.5	119.8	297.1	333.9	
Acceleration (°/s^2)	7822.9	10040.6	21051.4	3754.1	12203.0	11190.0	



(1)DEA OM interface (2)AS OM interface (3) CFW OM interface

(4) TE OM interface (5) MFW OM interface

Fig. 6. The optimized OM interface of a nuclear power system simulator.

(1)eye movement hotspot diagram (2)saccade path diagram

Fig. 7. Eye movement analysis example of the optimized CFW OM interface.

Table 6
The statistical saccade distance of optimized OM interface (unit: pixel).

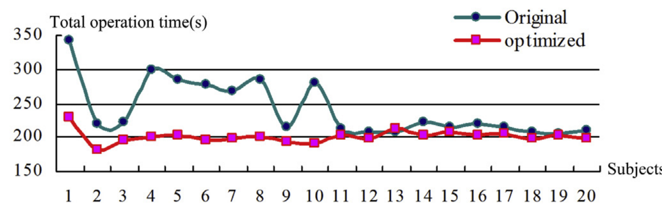
Saccade distance	20 subjects of experiment									
	1	2	3	4	5	6	7	…	19	20
Minimum	0.4	0.4	0.7	0.5	0.8	0.6	0.1	…	0.3	0.5
Maximum	1636.5	458.2	1068.4	831.7	1109.2	557.6	1171.5	…	1256.7	1791.9
Mean	137.1	96.6	116.4	111.3	113.9	95.1	148.7	…	83.5	91.9

Table 7
The statistical saccade velocity and acceleration of optimized OM interface.

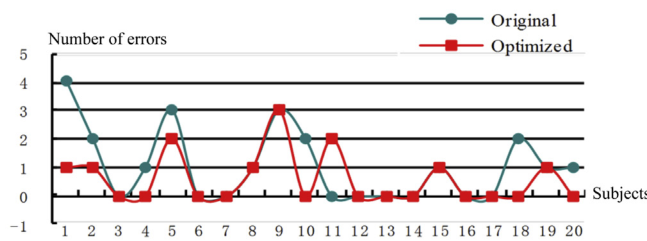
Velocity and Acceleration	20 subjects of experiment					
	1	2	3	4	…	19	20
Velocity (°/s)	182.6	96.3	228.6	333.4	…	141.8	196.2
Acceleration (°/s^2)	6180.7	4794.7	7223	11942.9	…	5119.1	6516.8

(2) As shown in Fig. 8 (2), operation errors appear both on the original OM interface and the optimized OM interface. After statistical calculation, the mean error rate of 20 subjects for the optimized OM interface is reduced from 105% to 60% in the experiment OM task. The operation safety of the optimized OM interface has been improved.

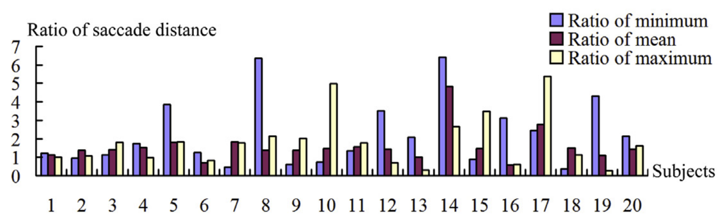
(3) As shown in Fig. 8 (3), the ratio of the minimum, the maximum and the mean of saccade distance is a statistical



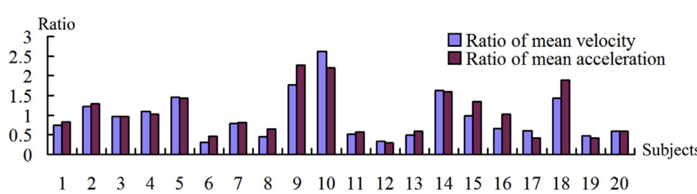
(1)Comparison of total operation time of subjects



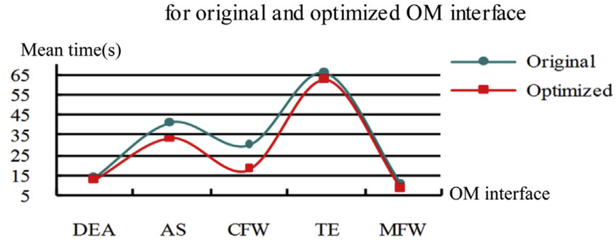
(2)Comparison of operation errors of subjects



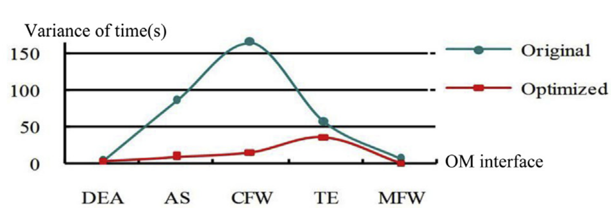
(3)Comparison of the ratio of saccade distance for original and optimized OM interface



(4)Comparison of the ratio of saccade mean velocity and mean acceleration for original and optimized OM interface



(5)Comparison of mean time for original and optimized OM interface



(6)Comparison of time variance for original and optimized OM

Fig. 8. Results comparison between original and optimized OM interface.

value for comparative analysis between the original OM interface and the optimized OM interface. When the ratio value is greater than 1, it means the saccade distance on the optimized OM interface is larger than the original OM interface. There are 14 ratio values greater than 1 in the ratio of the minimum, 18 ratio values greater than 1 in the ratio of the mean, 14 ratio values greater than 1 in the ratio of the maximum in 20 subjects. And the mean of ratio of mean saccade distance mean for 20 subjects is 1.58. It indicates that the information searching paths become simpler, and subjects can locate important information with fewer eye saccade. The cognitive information efficiency of the optimized OM interface is optimized, drift less search eye movement, and the number of search path decreased.

(4) As shown in Fig. 8 (4), the ratio of saccade mean velocity and mean acceleration is indirect approach for information searching efficiency analysis. When the ratio value is lower than 1, it means the saccade on the original OM interface is more and faster than the optimized OM interface. It reflects more information searching on the original OM interface. There are 7 ratio values lower than 1 in the ratio of saccade mean velocity, 9 ratio value lower than 1 in the ratio of the mean acceleration in 20 subjects. The optimized OM interface has a slight improvement. The mean saccade velocity and the mean acceleration of the optimized OM interface are lower than the original OM interface. It declares that distractive elements of OM interface decreased, and subjects' attention could be more focused on the important elements of the optimized OM interface for nuclear power system.

(5) As shown in Fig. 8 (5) and (6), the mean task time of the optimized OM interface is slightly lower than the original OM interface. The variance the typical task time of the optimized OM interface decreased, which indicates that the adaptability to the optimized OM interface had increased. The total time for subjects to spend on typical tasks on the optimized OM interface had decreased.

5. Conclusion

The cognitive load of OM interface is important for effective and safety operation of nuclear power system. This paper presented a new approach for cognitive load of OM interface for nuclear power system. To address this issue, cognitive load of OM interface is studied, and then cognitive load model of OM interface for nuclear power system is constructed based on the cognitive resource limitation theory and schema theory. Based on eye movement patterns and related data, the experiment method of eye movement is proposed to measure cognitive load of OM interface. With the model and method, experiment case is carried out on OM interface for a nuclear power system simulator, and based on experiment results, the OM interface is optimized. The model consists of three basic elements including the internal, external, and germane cognitive loads of OM interface, which are sources for reducing the cognitive load. Therefore, the model is valuable for understanding the cognitive load state of nuclear power system. The constructed cognitive load model is a contribution for OM interface design and analysis. The experiment eye movement method proposed in this study is a valuable contribution to measure the cognitive load of OM interface in nuclear power system. It is new approach for the eye movement method to be applied in such an application, which is better than existing scale evaluation methods, with advantages that not only records the physiological data in real time, but also measures the physiological data more accurately. It has significance for OM interface design and optimization of nuclear power system.

References

[1] Y.-T. Li, L. Zhang, H.-Q. JIA, “The study of the type of operation task and time pressure on cognitive load of digitized nuclear power plant operator's monitor behavior, Appl. Energy Tech. 6 (2016) 52–58.
[2] X.-F. Wu, S.-Z. ZHOU, How to reduce the cognitive load in interaction design, J. HUBEI Corres. Univ. 30 (8) (2017) 110–111.
[3] J. Park, W. Jung, A study on the validity of a task complexity measure for emergency operating procedures of nuclear power plants-comparing with a subjective workload, IEEE Trans. Nucl. Sci. 53 (5) (2006) 2962–2970.
[4] B. Kelvin, F. Iain, W. Louis, M. Eugene, Examining the relationship between visual attention and stated preferences: a discrete choice experiment using eye-tracking, J. Econ. Behav. Organ. 144 (2017) 238–257.
[5] C.l. Storto, Evaluating ecommerce websites cognitive efficiency: an integrative framework based on data envelopment analysis, Appl. Ergon. 44 (6) (2013) 1004–1014.
[6] J. Son, H. Oh, M. Park, Identification of driver cognitive workload using support vector machines with driving erformance, physiology and eye movement in a driving simulator, Int. J. Precis. Eng. Manuf. 14 (8) (2013) 1321–1327.
[7] F.-W. Wu, R. Fu, Z.-L. Niu, “Driver's fixation transition mode during lane changing process, J. Trans. Syst. Eng. Inf. Tech. 24 (2014) 68–73.
[8] J.-N. Sun, Kai Qiu, S.-T. Zhang, Evaluating method of product modeling design elements based on eye movement data, J. Mach. Des. 34 (10) (2017) 125–128.
[9] C.-H. Ha, J.-H. Kim, S-Jun Lee, Investigation on relationship between information flow rate and mental workload of accident diagnosis tasks in NPPs, IEEE Trans. Nucl. Sci. 53 (3) (2006) 1450–1459.
[10] W.-J. Hou, Y. Qin, Mobile typical interface structure based on eye-tracking browsing rules, J. Beijing Univ. Posts Telecommun. 16 (1) (2014) 25–30.
[11] R.-S. Sun, M. Wang, S. Dong, Analysis of gaze in simulated flight based on non-contact eye tracker, Chin. J. Ergonomic 9 (4) (2013) 51–55.
[12] Y.-T. Li, L. Zhang, H.-Q. JIA, The study of the type of operation task and time pressure on cognitive load of digitized nuclear power plant operator's monitor behavior, Appl. Energy Tech. (6) (2016) 52–57.
[13] X. Wang, S.-L. Sun, On the approach to measuring the air traffic controllers' cognitive load on account of the complexity of the air traffic, J. Saf. Environ. 18 (5) (2018) 1881–1885.
[14] C.-Y. Sun, Cognitive load measurement and its application in multimedia learning, Doctoral dissertation of Suzhou university, 2012, pp. 3–8.
[15] Y.-T. Li, L. Zhang, H.-Q. JIA, The study of the type of operation task and time pressure on cognitive load of digitized nuclear power plant operator's monitor behavior, Appl. Energy Tech. 6 (2016) 52–58.
[16] A. Murata, D. Fukunaga, Extended fitts' model of pointing time in eye-gaze input system-incorporating effects of target shape and movement direction into modeling, Appl. Ergon. 68 (2018) 54–60.
[17] R. Barnes G, Cognitive processes involved in smooth pursuit eye movements, Brain Cogn. 68 (2008) 309–326.
[18] J.S. Ha, Y.-J. Byon, J. Baek, P.H. Seong, Method for inference of operators' thoughts from eye movement data in nuclear power plants, Nucl. Eng. Tech. 48 (2016) 129–143.
[19] C.-W. Yanga, T.-L. Hsieha, S.-F. Linb, Operators'signal-detection performance in video display unit monitoring tasks of the main control room, Saf. Sci. 49 (10) (2011) 1309–1313.
[20] J.L. Zhang, The Research of Digital Human-Computer Interface Evaluation Method of Operation and Monitoring System for Nuclear Power Plants, Harbin engineering university, 2014, pp. 111–112.