Study on Eye Movements of Information Omission/Misjudgment in Radar Situation-Interface

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Abstract. Radar situation interface belongs to a sub-interface of a complex system. Because the information in human-computer interaction interface of a complex system is of a large amount and in complicated relationships, it is apt to cause misreading, misjudgment and information omission in the target search. The critical factors causing error problems like information omission and misjudgment in the radar situation interface are analyzed. Based on the behavioral data and the physiological data derived from eye movement tracking, the misperception factors leading to users' information omission/misjudgment are detected. The experimental results showed that, (1) Both interval size and vision position impose a significant influence on the visual cognition of target search. The interval should not be too large for target search in the situation interface, otherwise it may result in long reaction time and omission and misjudgment. (2) During the target search in the upper vision, lower vision and peripheral vision, the reaction time and the error rate present significant changes, and the reaction time of peripheral vision achieves the longest. The vision position also exerts a remarkable influence on the first saccade latency. The fixation duration and fixation point number display obvious changes, and the mean fixation duration of the lower vision is the longest while its fixation point number is the smallest, which is apt to cause misjudgment and omission of information. (3) Eye movement plots can effectively reflect the process of information search, and the gaze plot and the heat point map can present the relevant factors of information omission. And the conclusion reached can be used as reference for the information design and layout of the situation interface of future complex system, so as to effectively improve the misperception problems like omission and misjudgment in the target search process.

Keywords: Radar Situation Interface, Information identification, Omission, Misjudgment, Misperception, Visual perception, Eye movements.

1 Introduction

With the rapid development of industrial design and computer interactive media, visual information interface has become an essential information interactive medium in a

D. Harris (Ed.): EPCE 2014, LNAI 8532, pp. 407–418, 2014.

complex system. The unreasonable design of interface information has given rise to malfunctions of cognition and decision-making among operators, thus leading users into a complex cognition and finally resulting in serious failures in information recognition and analysis, and even in operation and execution processes, which poses one of the major causes for many accidents. Errors are common human failures occurring in information interface and its cognition mechanism of errors is an important hitting-point for improving interface design as well as the key for reducing cognition difficulties. Radar situation interface belongs to a sub-interface of a complex system. Because the information in human-computer interaction interface of a complex system is of a large amount and in complicated relationships, it is apt to cause misreading, misjudgment and information omission in the target search. It exerts a significant influence on improving the interface layout for effectively detecting misperception factors causing information omission, misreading and misjudgment.

2 Background

Error problems like information omission/misjudgment are mainly originated from the studies on error factors. The studies conducted by domestic and foreign researchers on systematic disorder and human error mainly focus on error analysis and human reliable methods. Embrey, Altman, and Swain, et al. tried to use the basic behaviour component of the operator to describe the behavior of the operator with "error" event characteristics from the view of traditional human factors; PHEA and HRMS et al. established the analysis model of human factor from the perspective of cognitive psychology. Nielsen[1] (1994) and Shryane[2] (1998) proposed the availability interface design method to reduce human error probability (HEP). Hidekazu[3] (1999) studied human error probability (HEP) through user evaluation model. And Krokos and Baker[4] (2007) also proposed interface cognition error classification method. Maxion[5] (2005) improved operation interface dependability through mitigation of human error (External Subgoal Support). Li Pengcheng[6], (2011) conducted a study on human error and reliability in digital control system of nuclear power plant, analyzing the error model of the missions of operators in nuclear power plant and establishing the risk evaluation model of human factor reliability of digital control system. Shappell[7-8] (2001, 2007) demonstrated the corresponding cognitive factors, like attention and understanding, with the technology and decision after analyzing the aircraft accident data from past 13 years; concluded the error probability in perception level was relatively low.

Domestic and foreign studies on the complex information interface mainly emphasis on the reasonability evaluation method of interface design; Wilson[9] (2005) used eye tracking technology to conduct the trial on FS35 fighter interface, tested the prospective memory and attention diversion of pilots and determined the cognitive complex factors of pilots. Wang Haiyan, Xue Chengqi[10] (2011) have experimentally evaluated and analyzed the layout design of fighter radar situation-interface through an objective evaluation technology of eye tracker, and selected a rational special layout optimization scheme through the evaluation by eye moving data indexes. Liu

Qing [11] (2012) simulated the general operation sequence of enemy attack task in avionics system to conduct interface design on infrared radar system, navigation system, weapon mounting system and flight control system, and evaluated the rationality of interface layout, navigation and graphic symbols by the eye tracker experiment. Li Jing and Xue Chengqi [12]et al. (2012) have studied the influence of the time pressure of complex digital interfaces on color and shape codes, to explore the identification performances under different time pressures. Dong Xiaolu[13]（2010）researched time press impact of digital interface from human error. For all the studies mentioned above, the experimental data are adopted as the main evaluation method to judge the rationality of complex information interface design. Few scholars have set foot in such fields like the reasons of information omission/misjudgment.

3 Method

The paper simulated the radar situation-interface of complex system. The nested cognitive experiment of reaction time and eye movement tracking was conducted. The analysis of variance method was applied to statistically analyze the indexes of reaction time and error rate as well as the indexes of gaze plot and fixation duration in eye movement data and the issues were discussed how the visual position and interval influenced target search and resulted in problems like omission and misjudgment caused by misperception. The experiment was divided into two parts: first, E-Prime was adopted to design software for reaction time experiment on stimulus features and then physiological measurement technology was employed for eye moving experiment on visual position. The study mainly analyzed the influence of eye movement indexes including total fixation duration, fixation count and saccade latency on the error factors of information omission/misjudgment.

4 Experiment 1: Visual Confined Research

4.1 Method

The experiment discussed the visual search in radar situation interface from two variables of visual position and target object interval, and founded that the visual position and target object interval served as the key factors which affected the visual limitation to result in omission and misjudgment. According to the six feature items of samples, the experiment will investigate the numbers of enemy plans, friend planes and unidentified objects that will appear. Experiment 1 adopted 3×2×3 with-in group design, with the three factors respectively being quantity of target objects (2, 4 and 6), visual position (upper vision and peripheral vision) and target object interval (12mm, 48mm and 96mm). The experimental procedure was written by the professional psychological experiment development software E-Prime. The experiment was conducted in the Human-Computer Interaction Lab of Hohai University, and the experimental subjects were 20 undergraduate students in the university.

4.2 Result

The study adopted the simulated fighter information matters as the experimental materials and conducted the experiment from the point of errors. The experimental result showed that, during information identification, with the gradual increase amount of information matters (two, four and six), the reaction time of target objects in peripheral vision display a gradually increasing trend compared with those in upper vision, and that the reactions of searches for target objects with different intervals reached remarkable levels. When enemy planes, friend planes and unidentified objects appeared in different visual positions of attack interface in the form of simulants and were presented in different numbers and intervals, the reaction times and error rates of subjects were shown in Fig.1. The variance analysis on reaction times showed that, the main effect of intervals of upper visual positions ($F=14.416$, $P=0.012$, $p<0.05$) and that of peripheral visual positions ($F= 6.990$, $P= 0.00103$, $p<0.05$) both reached remarkable levels. The variance analysis on error rates showed that, the main effect of intervals of upper visual positions ($F=2.380$, $P=0.013$, $p<0.05$) and that of peripheral visual positions ($F=9.308$, $P= 0.014$, $p<0.05$) reached remarkable levels. Hence, the size of intervals can exert a significant influence on the visual cognition of target search in visual positions. The analysis extracted the data collected under a high error rate and found that, the target search with different interval information showed a linear increase on the error rate, while displaying an inverted-V during the reaction. Therefore, errors like misjudgment and omission did not necessarily require the longest reaction time.

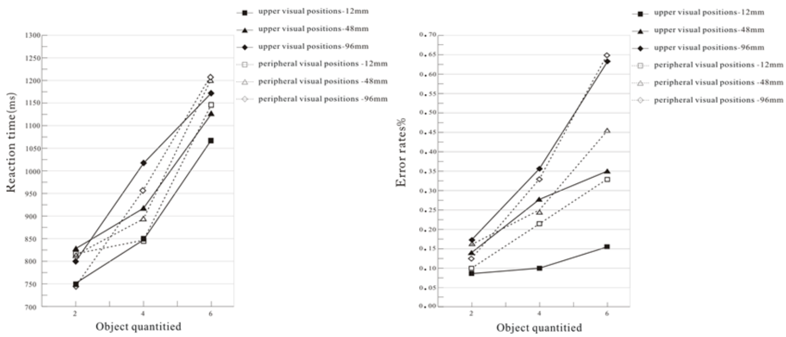

Fig. 1. Reaction time and Error rates in three intervals under different vision positions

5 Experiment 2: Eyes Movement Research

5.1 Method

Material. The stimulus feature items were designed as the simulated information matters in radar AD-attack situation interface of a complex system, specifically, they were the enemy planes, friend planes and unidentified objects, including six objects of green friend planes, red enemy planes and four unidentified objects of green, red and yellow) whose size was fully filled up in black boxes. The enemy planes, friend planes, red and green unidentified objects appeared alternatively. Since red and green colors existed in the attack situation interface which possessed a strong interference, the yellow unidentified objects only serves as interference items rather than the target objects for investigation to reach the same interference strength of target objects. The stimulus feature items were designed as the same in radar AD-attack situation interface in experiment 1. All the materials are presented in the attack situation interface with a radius of 78mm. The circle with a radius of 39mm was the attack range and the pattern of the host computer was in the center. Various data of current situation were presented in around mainly in white, red and green, which would further impose fixed intervention on subjects. All of these presentation elements were quantitative data and formed a complex situation environment. However, the enemy planes, friend planes and unidentified objects acted as variables and were presented within the annulus constituted by large circles and small circles.

Apparatus. The experiment was conducted in the eye movement tracking laboratory of HHU (Hohai University). The Switzerland-made tobii1X120 eye tracker with a sample frequency of 120HZ and gaze location precision of 0.5 degrees was adopted. The computer with a display pixels of 1280×1024 (px), a color quality of 32-bit, a collection way of eyes collection and a head movement range of 30×16×20cm, was was adopted. The sight-line gaze location data of the system were delayed to 3ms and possessed an ideal gaze - instantaneous display. The system took samples from the eyeballs of subjects every 20ms, to investigate and collect the data of eyeball movement of subjects.

Participants. The experiment was conducted in the Human-Computer Interaction Lab of Hohai University, and the experimental subjects were 20 undergraduate students in the university, 10 females and 10 males, aging between 19 and 23 years old, with normal vision or corrected vision, and without color blindness or color weakness. Before the experiment, relevant information of the subjects were input, including their gender, age, major and vision.

Procedure. The subjects were first required to be familiar with the task environment of radar attack situation; information in such situation environment remained unchanged and the interference from the information should be avoided. Then, the features (colors and shapes) of target objects including enemy planes, friend planes and unidentified objects were informed, which would be considered as the objects of target search. At the beginning of the experiment, the subjects were asked for the number of enemy planes, friend planes or unidentified objects appearing in the situation environment and required to remember the targets they were searching for; the presentation of the target objects was set at 1,500ms. After the screen was blackened, nine stimulus items would appear, among which, 6±1 target objects were required to be searched by subjects; during the presentation of 1,500ms, the subjects were asked to rapidly figure out the number of target objects appeared and press the number key for reaction after the black screen. It cost about 15 minutes for each one to perform an entire experiment.

Design. On the basis of analysis the data from experiment 1, experiment 2 adjusted the setting of independent variables and further discussed the error-prone (omission and misjudgment) visual limitations. Six target objects were regarded as the basic quantity of visual search and then were adjusted to 6±1 in order to cause quantitive randomness to subjects. To further understand the positional characteristics, the lower vision factor was added. The interval design had excluded the single interval of 12mm and mainly probed into four fold and eightfold intervals.

5.2 Result and Discussion

Gaze Plot. The data derived at the earliest by eye movement tracking experiment is the Gaze Plot. The gaze plots in different vision locations were shown in Fig.2. At the field of upper vision, the subjects could focus on searching the number of enemy planes in the upper visual area; when subjects searched the enemy planes in the lower visual area, it could be clearly detected that, the subjects would spontaneously glance the upper visual area and be interfered by the upper vision. However, their gaze plots in peripheral visions were more scattered and the integral glancing paths covered a larger area of upper vision. As a result, a discussion on the information search in radar situation interface based on vision locations is of distinctive features. The factors causing information omission and misjudgment can be discussed from the perspectives of the gaze plot and the location of target objects.

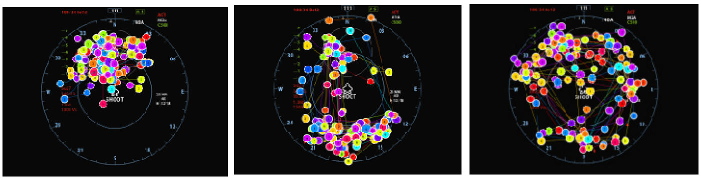

Fig. 2. Fig.2 Gaze plots under different vision positions (Left: the upper vision; Middle: the lower vision; Right: the peripheral vision)

The subjects were asked to figure out the total number of the enemy planes appeared. Fig.3 showed the gaze plots of one subject's target search in the upper vision and the lower vision, respectively. The left figure displayed seven fixation points of the subject; the first fixation point is near the center and then moved to and stayed at the red data part; afterwards, the fixation point continued to stay from the influence of icons in the upper attack range; the subject began to search the target objects again until the sight reached the fourth fixation point. Obviously, it was difficult for this subject to search out all enemy planes within 1,500 ms, and which lead to the omission of target objects. The number of fixation points of the subject in the right figure was eight, but his former three fixation points all stayed at the red area within the attack range and was transferred to the target objects of lower vision until reaching the fourth fixation point. This demonstrated during target search, other irrelevant non-target information matters (the unidentified objects and information data display, etc.) become the interferents of information search and occupy the fixation duration, therefore, causing attention shift.

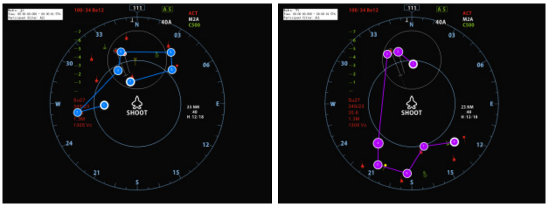

Fig. 3. Gaze plots of one subject's target search respectively in the upper vision and the lower vision

Heat Map. The heat map composed through the region of interests of twenty subjects shows the heat points distribution of the upper vision (the left figure in Fig.4), the lower vision (the middle figure in Fig.4) and the peripheral vision (the right figure in Fig.4). Among which, the brightest red area indicates the subject presents a longest gazing time and that the largest number of the fixation points distributed in that area. However, the heat point area simultaneously appearing both in the upper vision and the peripheral vision acts as the indicator icons of attack range, which suggests that this information indication has seriously impacted the target search and is the essential factor causing information omission. It can be further illustrated based on the duration and times of fixation points.

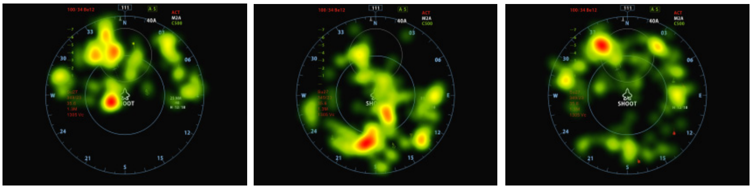

Fig. 4. The heat point map in different vision positions (Left: the upper vision; Middle: the lower vision; Right: the peripheral vision)

Total Reaction Time and Error Rate. When the enemy planes appear in the upper-middle, lower and peripheral vision positions of attack situation interface in the form of stimulants with other unidentified objects distributed around, the reaction time and error rate of the subject when the objects are presented in two different intervals are shown in Fig.5 and Fig.6. The variance analysis on the reaction time shows that, the interval main effects of the vision position（F=81.227，P=0.004，p<0.05）has reached remarkable levels. The variance analysis on the error rate suggests that, the interval main effects of the vision position (F=7.562，P=0.021，p<0.05) has reached remarkable levels. Therefore, the vision position exerts a significant influence on the visual cognition of target search.

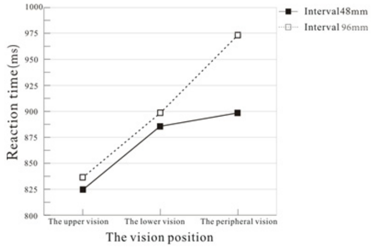

Fig. 5. The reaction time in different vision positions

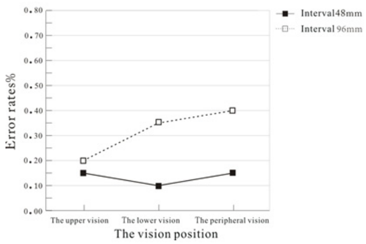

Fig. 6. Error rates in different vision positions

Mean of Fixation Duration. The mean fixation duration of fixation points refers to the ratio of the Total Fixation Duration to the Fixation Count in the task. During a normal visual observation, the performance of eye movement is reflected by the rapid saccade between a series of sight stay and the staying points on the observed object. The stay of eye movement for at least 100ms is generally called the fixation. Most information can be processed only during the fixation. Therefore, the process of target search is significantly influenced by the vision positions. The fixation duration and fixation times of the upper vision are greatly larger than those of the lower and peripheral vision. In addition, they can easily capture the targets easier with few information omissions, as it shown in Tab.1.

Table 1. Mean fixation duration and fixation times

		Fixation Duration（Mean）	Fixation Duration（N）
The upper vision	Interval（48mm）	240	5.80
	Interval（96mm）	285	6.55
The lower vision	Interval（48mm）	490	4.15
	Interval（96mm）	365	5.10
Peripheral vision	Interval（48mm）	235	6.15
	Interval（96mm）	215	6.65

Time to first fixation refers to the position where firstly gazed by the eyeballs of the subject. The information configuration of the situation interfaces at three different vision positions is shown in Fig.7. The possible visual search areas are divided according to the positions of target objects and interferents depending on the distribution condition of the heat point map. The visual search areas in eye movement tracking areas are called the areas of interest. In which, AOI 1-4 are the areas which can be easily gazed by the eyeballs and also is the area where target enemy planes are located. The mean fixation duration in different areas can be acquired. From the areas of interest in Fig.10 which corresponds with the data listed in Tab.2, AOI3 in the upper vision displays the longest mean fixation duration (760ms), which further explains that the digital information in the upper left corner has received the highest intensified interference and can easily cause attention shift. When target objects appear in the lower vision, the time to the first fixation stays at the attack information indicating area (1040ms), followed by target objects presented in the lower vision (540ms). Since the color of the interferents (appearing in red) is the same as that of the target objects, it will easily lead to attention shift. As a result, the subject will easily take the unidentified objects as the enemy planes by misjudgment and lead to a wrong judgment.

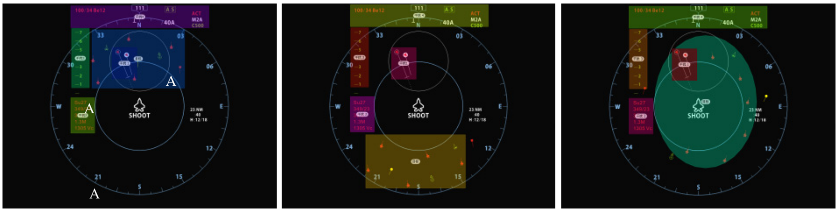

Fig. 7. AOS division at different vision positions (Left: the upper vision; Middle: the lower vision; Right: the peripheral vision)

Table 2. Fixation duration and fixation points divided by different areas of interests

Division of areas of interest	AOI 1		AOI 2		AOI 3		AOI 4		AOI 5	
	Sum N		Sum	N	Sum	N	Sum	N	Sum	N
The upper vision	330	19	170	1	760	1	-	-	150	20
The lower vision	1040	3	440	2	-	-	280	1	540	20
Peripheral vision	370	7	700	3	840	2	-	-	100	20

Saccade Latency. The first saccade latency refers to the time interval from the start of the stimulus presentation to the first saccade made by the subject, including the time required for information-in and out as well as the central processing time controlled by the pathways and its complexity. The variance analysis on repeated measure reveals that, the vision positions of target objects impose an appreciable influence on the first saccade latency of the subject. As it is shown in Fig.8, the reaction times in the vision positions have reached remarkable levels ($F= 3.571$, $P=0.036$, $p<0.05$). When the target object appears in the lower vision position, the first saccade latency of the subject is greatly longer than the presentation time of the target objects in the upper vision, which explains that the vision positions of the target objects have influenced the attention of the subject to some extent and lead to a delay in saccade time. The target object intervals exert an influence on the first saccade latency; relevant comparison shows that, the first saccade latency of the stimulus presentation in eight-time intervals is longer than that of the stimulus presentation in four-time intervals. The interactions between each variable are not obvious.

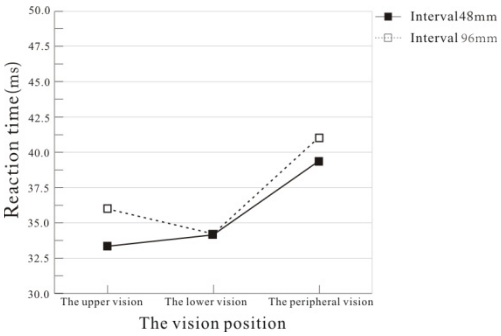

Fig. 8. Saccade latency

6 General Discussion

This experiment discusses the visual search of the radar situation interface based on two variables, i.e., vision position and target object interval. The experiment finds that, the vision position and target interval serve as the key factors influencing the visual limitation and further lead to errors like omission and misjudgment. The result of experiment 1 demonstrates that, during the information identification, with the increase amount of the information matters (two, four and six), the reaction time required by the target objects in peripheral vision is gradually increasing than that in the upper vision, and the target searches in different intervals have reached remarkable levels; the analysis extracts the data under high error rate and reveals that, during the visual searches of information with different intervals, the error rate displays a liner increase, while the reaction time presents an inverted-V change. Therefore, the errors like misjudgment and omission do not necessarily require the longest reaction time. Wickens et al. [15](1990) studied the identification on the information with different color codes and spatial positions under multiple information channels, and proposed the different influences of colors and positions on the information identification; Dukic and Hanson[16-17] (2005,2006) studied the visual search mode of pilots and proposed relevant strategies for visual search. Based on previous conclusions, experiment 2 selects the vision position and the target interval as variables. Since these two variables are the key factors of relevant visual limitation, and the target objects are easier to be omitted in the lower vision and peripheral vision. The result of experiment 2 indicates that, the vision position and the other information matter in visual area are the main factors that prone to cause the omission and misjudgment in visual search; particularly, in the lower vision and the peripheral vision, target objects are easier to be subject to omission. The eye movement study in experiment 2 further discusses the visual limitation prone to errors (omission and misjudgment, etc.) basing on experiment 1. Six target objects with high error rates are regarded as the basic amount of the visual search, and the experiment obtains the eye movement plot and heat map based on the data of eye movement experiment from three different visions. In addition, the fixation duration and fixation times of omission and misjudgment are also analyzed, and the rules of eye movement of visual search of subjects are concluded from physiological data. The experiment finds that, because the eyes are accustomed to following the visual rule of from the left to the right and from the upper to the lower, during the target search in the lower vision, the subject will always start the search the other information matters from the upper vision, and begin the search for the target objects in the lower vision in the second and third saccade. The first saccade latencies in the lower vision and peripheral vision are obviously longer than those required by the target object presentation in the upper vision. Furthermore, the experiment finds that, the visual interference will also cause omission and misjudgment; sequence experiments on the visual interference factors are demanded. There are many information matters in the radar situation interface which are deserved to be simulated and tested in the classified simulated situation environment, which is meaningful for the further study.

7 Conclusion

Both interval size and vision position impose a significant influence on the visual cognition of target search. The interval should not be too large for target search in the situation interface, otherwise it may result in long reaction time and omission and misjudgment. During the target searches in upper vision, lower vision and peripheral vision, the reaction time and error rate present significant changes and the reaction time required in peripheral vision is the longest. The fixation time and fixation point number also show significant changes; the mean fixation time of lower vision is the longest, but the fixation point number is the smallest, which is easier to cause information misjudgment and omission. The eye movement plot can effectively reflect the process of information search; the fixation plot and heat map can present relevant factors of information omission; different vision positions and intervals also exert an appreciable influence on the first saccade latency. The vision position is not regarded as the most essential error factor; the data of eye movement explain the features of information matters, such as the color and shape, are easier to cause attention shift leading to information omission.

Application. The study was not conducted in a real fighter cabin and the information matters of enemy plane, friend plane and unidentified objects were all simulated, so the data obtained are simulated data, and the conclusion reached can be used as reference for the information design and layout of the situation interface of future complex system, so as to effectively improve the misperception problems like omission and misjudgment in the target search process.

Acknowledgment. This work was supported by the National Nature Science Foundation of China（Grant No.71071032,71271053，the Social Science Fund for Young Scholar of the Ministry of Education of China(Grant No. 12YJC760092), and Fundamental Research Funds for the Central Universities of China (Grant No. 2013B10214)，

References

1. Nielsen, J., Mack, R.L.: Usability Inspection Methods. Wiley, New York (1994)
2. Shryane, N.M., Westerman, S.J., Crawshaw, C.M., Hockey, G.R.J., Sauer, J.: Task analysis for the investigation of human error in safety critical software design: a convergent methods approach. Ergonomics 41(11), 1719–1736 (1998)
3. Yoshikawa, H., Wu, W.: An experimental study on estimating human error probability (HEP) parameters for PSA/HRA by using human model simulation. Ergonomics 42(11), 1588–1595 (1999)
4. Krokos, K.J., Baker, D.P.: Preface to the special section on classifying and understanding human error. Human Factors 49(2), 175–176 (2007)
5. Maxion, R.A., Reeder, R.: Improving user-interface dependability through mitigation of human error. International Journal of Human-Computer Studies 63(1-2), 25–50 (2005)
6. Pengcheng, L.: Study on human error and reliability in digital control system of nuclear power plant. South China University of Technology (2011)
7. Shappell, S.A., Wiegmann, D.A.: Applying Reason: The human factors analysis and classification system (HFACS). Human Factors and Aerospace Safety 1(1), 59–86 (2001)
8. Shappell, S., Detwiler, C., Holcomb, K.: Human Error and Commercial Aviation Accidents: An Analysis Using the Human Factors Analysis and Classification System. Human Factors 49(2), 227–242 (2007)
9. Wilson, J.R., Hooey, B.L., Foyle, D.C.: Head-Up Display Symbology for Surface Operations: Eye Tracking Analysis of Command-guidance vs. Situation-guidance Formats. In: Proceedings of the 13th International Symposium on Aviation Psychology, Oklahoma City, pp. 13–18 (2005)
10. Haiyan, W., Ting, B., Chengqi, X.: Experimental evaluation of fighter's interface layout based on eye tracking. Electro-Mechanical Engineering 27(6), 50–53 (2011)
11. Haiyan, W., Ting, B., Chengqi, X.: Layout design of display interface for a new generation fighter. Electro-Mechanical Engineering 27(4), 57–61 (2011) (in Chinese)
12. Qing, L.: Research on design and experiment method of avionics system display interface. School of Mechanical Engineering, Southeast University, Nanjing (2012) (in Chinese)
13. Jing, L., Chengqi, X., Haiyan, W.: Information encoding in human-computer interface on the equilibrium of time pressure. Journal of Computer Aided Design & Computer Graphics 25(7) (2013) (in Chinese)
14. Xiaolu, D.: Influence of human-system interface design method and time pressure on human error. Industrial Engineering Department of Tsinghua University, Beijing (2010) (in Chinese)
15. Wickens, C.D., Andre, A.D.: Proximity compatibility and information display: effects of color, space, and object display on information integration. Human Factors 32(1), 61–77 (1990)
16. Dukic, T., Hanson, L., Holmqvist, K., Wartenberg, C.: Effect of button location on driver's visual behaviour and safety perception. Ergonomics 48(4), 399–410 (2005)
17. Dukic, T., Hanson, L., Falkmer, T.: Effect of drivers'age and push button locations on visual time off road, steering wheel deviation and safety perception. Ergonomics 49(1), 78–92 (2006)