Research on the Effect of Cockpit Knob Interface Layout and Position on Change Blindness

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Abstract

The phenomenon of change blindness in the process of aircraft flying is easy to cause pilots to miss the key information prompt, resulting in huge safety risks. In order to ensure flight safety by reducing the occurrence of change blindness, this research adopts the forced detection paradigm and eye tracking technology, combining keystroke accuracy, reaction time, average fixation time, fixation point number to explore stimulus presentation time, knob interface layout complexity, and influence of the position of the knob on change blindness. Therefore, it provides theoretical guidance on how to reduce the incidence of change blindness. The results showed that increasing the time of stimulus presentation could improve the efficiency of change detection and reduce the probability of change blindness. The more concise and reasonable the knob interface layout is, the more beneficial it is in reducing the cognitive load of the subjects and improving the change detection ability of the subjects, thereby reducing the incidence of change blindness. The subjects tended to devote more attention to the central knob, and the identification and processing of information were more comprehensive, meaning the success rate of change detection was higher. It is also proved that there is no interaction between these factors.

1. Introduction

Aircraft flying is a process that requires real-time monitoring of cockpit environment changes, continuous attention to surrounding environmental information, continuous filtering of irrelevant information and making correct decisions. Vision, as one of the most widely used sensory channels, plays a crucial role in the driving process. Pilots rely on the vision system to detect changes in the scene at all times. If they fail to detect changes in the cockpit during the flight process, there may be serious consequences. For example, on February 4, 2015, the captain of Flight 235 of TransAsia Airways in Taiwan, China, took the initiative to remove the autopilot in case of the failure of the second engine. In the process of manual pilot, due to the operating pressure of high load and his own tension, the captain appeared to be affected change blindness. Forty-three people died and 15 got injured when the captain ignored the co-pilot's cross-check request and information of engine no. 2's automatic shunting. This inability to detect significant stimulus changes is called change blindness[1]. Change blindness usually involves two conditions: one is the failure to perceive a new stimulus, while the other is the failure to detect the changes of the original stimulus in the position and motion state[2].

In recent years, traffic accidents caused by change blindness remain high[3]; hence scholars have carried out corresponding studies on change blindness in the field of traffic. Studies on the influencing factors of change blindness can be divided into two categories: scene change characteristics and driver characteristics[4]. The characteristics of scene change can be further sub-divided into visual salience of change, security relevance of change, change position and scene complexity. In the field of road traffic, Galpin et al.[5] found through experiments that drivers are more likely to be alert to driving-related information in complex traffic scenes, but find it difficult to detect sudden irrelevant changes. Beanland[6] studied the difference in drivers' change detection of seven types of objects, including road signs, vehicles and pedestrians, in urban scenes and rural scenes, and categorised the safety correlation of the target objects. According to the results, drivers in rural areas showed more accurate and faster responses and were less affected by change blindness. In addition, the target of safety related to driving on the rural scene change detection have no obvious effect on performance, which is different in a city driving scene, where drivers prove to be more efficient in change detection of high security correlation targets. Beanland[7] also reported that the visual significance of the change of the target affected the subjects' efficiency of change detection, that is, the greater the difference of the change of the target before and after, the better the performance of the change detection of the subjects. In the experimental study of Zhao[8], with the centre of the screen as the origin, 25% of vertical and horizontal areas were defined as the centre area, and the rest as the edge area. The study results show that drivers perform better in scene change detection in the central area than in the edge area. In the field of civil aviation traffic, Mayo[9] applied eye-movement tracking technology to study whether the upgrade of the Synthetic Vision Systems (SVS) display system would reduce the incidence of change blindness in subjects, but the results showed that the improvement of display technology did not improve the efficiency of change detection in pilots. Ahlstrom[10] 's study showed that the complexity of information display in the SVS system increased the time of change detection and reduced the efficiency of change detection for pilots.

Driver characteristics can be divided into attention span and memory capacity, cognitive or psychological load, and level of driving experience. In the field of road traffic, Yanqun Yang et al.[11] explored the effects of emotion induction and driving tasks on change blindness through experiments, and found that both positive and negative emotions led to varying degrees of decline in the drivers' change detection level, but negative emotions had a more significant impact. Filtness et al.[12] studied the relationship between change blindness and drivers' sleepiness due to sleep deprivation, and found that sleepiness had no significant influence on the drivers' change detection level. Murphy[13] 's study proved that when a driver is under a high load, his cognitive resources will be too occupied, leading to a decrease in the detection efficiency of the change of the target, thereby making them prone to change blindness. The experimental study of Crundall[14] shows that drivers' ability to detect risk changes is correlated with their experience level. The richer the driving experience, the higher the detection efficiency of risk changes. Change awareness ability can be obtained through perception training. In the field of civil aviation traffic, Zarate[15] explored the change detection efficiency of aircraft pilots for aircraft display by taking professional knowledge level and regional position as influencing factors. The results showed that there was no significant difference between expert pilots and novice pilots in their response to change detection. McDermott[16] studied the visual search efficiency of pilots' experience level with the SVS display system, and found that pilots with low experience level perform better than those with high experience level in attention performance.

Based on the above analysis, it can be seen that current studies on the influencing factors of change blindness in civil aviation mainly focus on cockpit display and experience level. However, there are hardly any studies on the influencing factors and interaction of other control devices (such as knobs) that may cause change blindness. In addition, most of the above studies only take behavioral indicators or eye movement indicators as the measurement basis, and the occurrence of change blindness is largely due to behavioral and eye movement indicators [17]. Therefore, this study carries out an experimental investigation, taking the position of the knob interface layout as the influencing factors, with the eye movement index and behavior index as the basis, to analyze the interaction between these factors, and provide guidance for pilots regarding change blindness in the process of human-computer interaction.

2. Methods

This study has been approved by the Safety Research Institute of the Civil Aviation University of China ("Ergonomic Evaluation and Design of the Cockpit of a Large Fire-fighting Water Rescue Amphibious Aircraft (AG600)"). Cockpit images are from the Airbus A320 Pilot's Manual, the study was conducted in accordance with safety agency and FAA regulations, and has been certified by the Civil Aviation Administration.

2.1 Experimental subjects

A total of 33 students majoring in flight at Civil Aviation University of China were recruited to participate in this experiment. The subjects had basic professional knowledge of independent completion of the experiment, and were in the age range of 19–23 years, the average age was 20.8 ± 2.2, normal visual acuity or corrected visual acuity was above 1.0, and all of them were right-handed.

2.2 Experimental Platform

The equipment required for the experimental platform includes:

1. Eyeso Glass eye tracker (head-mounted, and captures eye movement through infrared dark pupil with a sampling rate of 100 FPS, accuracy of 0.08°, accuracy of 0.5°);
2. E-PRIME3.0 self-programmed experimental program;
3. Original Airbus A320 cockpit image before and after PS processing. The more the sightline detour times, the higher the redundancy, and the higher the cognitive complexity of the layout[18]. Cockpit images are classified (simple layout and complex layout) through pre-experiment screening, as shown in FIG. 1.
4. 14-inch laptop: resolution 1366×768.

2.3 Experimental Procedure

The specific experimental steps are as follows:

(1) Subjects were required to fill in the informed consent form to ensure that their physiological and psychological states met the requirements of the experiment;

(2) All devices were connected to the power supply, and the subjects were placed 0.7m in front of the computer screen and told to maintain the correct sitting position;

(3) After the eye tracker was turned on, the subjects were asked to wear the eye tracker for calibration to ensure that the instrument could accurately record the position observed by the eyes of the subjects;

(4) The behavioral index data of the subjects were collected by E-Prime self-programmed experimental program, and eye movement data were collected by the eye tracker equipment.

2.3.2 Experimental structure

The experiment adopts a 2×2×3 structure

Factor A: The presentation time of the experimental images were 250ms, 350ms and 450ms, respectively. The presentation time of forced selection detection paradigm is generally within the range of 100-500ms [19].

Factor B: image layout; divided into complex interface layout and simple interface layout.

Factor C: knob position; divided into central position and edge position.

Dependent variables: 1) The accuracy of key response 2) Reaction time; 3) Average fixation time 4) Number of fixation points.

2.3.3 Experimental process

A single experiment flow is shown in the Fig. 2 below (taking the stimulus presentation time of 250ms as an example). Each subject was asked to look for differences between the images presented before and after. At the beginning of the experiment, a 1000ms "+" fixation point was presented in the center of the screen to prompt the subjects to pay attention to the screen. Then, the first original Image A (250ms) was presented, and a gray screen was then placed in the middle of the screen for 100ms to allow the subjects' eyes to relax properly. Finally, the second image A' (250ms) was presented. A blank page for button response was then shown, and the subjects were asked to make A button response to indicate whether there was any difference between the two images (A and A '). If a subject did not make A response within the specified time of the experimental task, the system did not generate a correct A response by default. The experiment consisted of 45 trials, including 12 practice trials and 32 formal trials, each of which lasted for about 10 minutes.

3. Pretreatment Of Experimental Data

3.1 Screening of eye movement data

Once the experiment was complete, the eye movement data of the subjects were generated. The original eye movement data recorded by the eye tracker were screened according to the confidence degree of the eye movement data. The confidence degree is the quantification of the reliability of the measured value by using the pupil detection algorithm [20], and the confidence degree ranges from 0 to 1. The higher the confidence value the higher the reliability of the data. When the confidence value is between 0.8-1, it means the eye movement data can be used as reliable experimental data. At the same time, when the confidence value is below 0.8, it means the experimental data of the subject is not reliable enough and should be discarded. Therefore, eye movement data with confidence values lower than 0.8 were screened out from the experimental data, and the eye movement data of two subjects that did not meet the experimental requirements were eliminated.

3.2 Screening of behavioral indicator data

In the experiment process, the response time and accuracy rate of the subjects were recorded by the experimental program as the measurement index. In the data screening of behavioral indicators, the data was preprocessed to eliminate the data of a subject that deviates from the threshold significantly, to ensure the accuracy of the experimental data.

4. Results And Analysis

4.1 Analysis of behavioral indicator results

4.1.1 Mean analysis

The accuracy rate of keys reflects the number of times the subject correctly completed the experiment during the experimental task and the success rate of the change detection of the subject. The reaction time represents the reaction time taken by the subject to complete the task and reflects the change detection time of the subject [21]. From these two behavioral indicators, we can analyze the performance of change detection of the subjects under different influencing factors.

The experimental data of the two behavioral indicators of 30 subjects were summarized to obtain the average response rate and response time (unit: ms) of the subjects in different knob interface layouts, different stimulus presentation times and different knob positions. The results are shown in Table 1 below.

Table 1
The average value list of subjects' keystroke accuracy and key response n = 30

Independent Dependent variable variable	Stimulus presentation time 250ms 350ms 450ms	Interface layout simple complex	Position area central edge
M Correct rate SD	0.848 0.871 0.892 0.044 0.036 0.035	0.856 0.885 0.401 0.390	0.861 0.880 0.044 0.385
M Reaction time SD	381.147 319.244 256.757 84.959 53.845 46.992	331.302 306.797 75.664 85.778	341.270 296.829 84.152 72.844

Table 1 shows that: under the conditions of different stimulus presentation times, different interface layouts and different knob positions, there were differences in the subjects' average keystroke accuracy, and mean and standard deviation of response times. The basic trend was that the shorter the stimulus presentation time, the lower the average accuracy of responses, and reached the highest at 450ms (M = 0.892, SD = 0.035). The reaction time at 250ms was the lowest (M = 0.848, SD = 0.044), the average reaction time was shortest at 450ms (M = 256.757, SD = 46.992) and longest at 250ms (M = 381.147, SD = 84.959). The more complex the interface layout the lower the average keystroke accuracy and the longer the average response time. Meanwhile, the average keystroke accuracy of the knob in the central position is higher than that of the edge position, and the average response time when the knob is in the central position is significantly lower than when it is in the edge position.

In order to more clearly and intuitively analyze the keystroke accuracy rate and reaction time of each subject under different influencing factors, Origin software was used, as shown in Fig. 3.

As can be seen from the figure above, due to individual differences, each subject has different performance in keystroke accuracy and reaction times, but there is consistency in the overall trend. By observing the first and second images in Fig. 3, it can be found that with the increase of stimulus presentation time, the keystroke accuracy of each subject also increases gradually, while the response time decreases gradually. It can be seen from the third and fourth figures that the keystroke accuracy rate of each subject in the complex interface layout is generally higher than that in the simple interface layout, and the response time tends to be relatively longer. A closer look at the fifth and sixth images also shows that subjects had a higher rate of correct keystrokes and shorter response times in the central position than in the edge position.

From the analysis of population mean and individual mean, it can be concluded that the stimulus presentation times, interface layouts and position areas all affect the efficiency of change detection. The shorter the stimulus times the lower the success rate of change detection, and the longer the change detection time. The change detection accuracy of the complex interface layout is lower than that of a simple interface layout, and the longer the change detection time. The success rate of change detection in the central position is higher than that in the edge position, and the change detection time is relatively shorter.

4.1.2 Analysis of variance

In order to further analyze the interaction between different influencing factors, SPSS was used to conduct variance analysis. Image presentation times (250ms/350ms/450ms), complexity of knob interface layout (complex/simple) and the knob position (central position knob/edge position knob) were taken as independent variables. The accuracy of keystrokes and reaction times were taken as dependent variables.

The test results are presented in Table 2 and Table 3. The results show that the values of the keystroke accuracy and reaction times are statistically significant ($P > 0.05$), and the data meet the conditions of variance analysis.

Table 2
Variance homogeneity test of keystroke accuracy

Levin statistics	Degree of freedom 1	Degree of freedom 2	Significance
0.757	11	168	0.682

Table 3
Test of homogeneity of variance during reaction

Levin statistics	Degree of freedom 1	Degree of freedom 2	Significance
1.767	11	168	0.063
The ANOVA results of the keystroke accuracy rates and response timed are presented in Table 4 and Table 5.			

Table 4
ANOVA table of keystroke accuracy

Variation source	Class III sum of squares	DOF	Mean sq-uare	F	Significa-nce
Interface layout	.037	1	.037	30.616	.000
Stimulus time	.058	2	.029	23.996	.000
Position area	.017	1	.017	13.795	.000
Layout * Time	.002	2	.001	.943	.392
Layout * Position	.000	1	.000	.126	.723
Time * Position	.001	2	.000	.326	.722
Layout*Time*Position	.002	2	.001	.784	.458

Table 5
Analysis of variance during reaction

Variation source	Class III sum of squares	DOF	Mean squar-e	F	Significa-nce
Interface layout	27022.734	1	27022.734	8.366	.004
Stimulus time	464186.852	2	232093.426	71.853	.000
Position area	88876.636	1	88876.636	27.515	.000
Layout * Time	7101.451	2	3550.726	1.099	.336
Layout * Position	18675.772	1	18675.772	.082	.617
Time * Position	207.277	2	103.63	.032	.968
Layout*Time*Position	42668.223	2	21334.111	1.072	.339

From Table 4 and Table 5, it can be concluded that the stimulus presentation time, interface layout, and knob position all showed significant effects ($P < 0.05$) in terms of correct rate and response time ($P < 0.05$), that is, different stimulus presentation time, different stimulus presentation time There were significant differences in the keystroke accuracy and response time of different interface layouts and different knob positions, but there was no interaction between the three ($P > 0.05$).

The LSD test was used for multiple comparison of the differences of the subjects' keystroke accuracy and response times corresponding to different stimulus presentation times.

Table 6
Multiple comparative analysis table of keystroke accuracy and response times

	(I)Time	(J)Time	Significance(keystroke accuracy)	Significance(reaction time)
LSD	250	350	.002	.000
		450	.000	.000
	350	250	.002	.000
		450	.002	.000
	450	250	.000	.000
		350	.002	.000

Through multiple comparison in Table 6, it can be found that the P values among the three factors are all less than 0.05 at 250ms, 350ms or 450ms, indicating that there are significant differences in the keystroke accuracy and response times.

In order to further intuitively compare the interaction among the three in terms of keystroke accuracy and response time, Origin was adopted to make the interaction diagram shown in Fig. 4.

By observing the first and second images in Fig. 4, it can be seen that there is no significant difference between the stimulus presentation time at different knob positions and different interface layouts in terms of keystroke accuracy. In other words, there is no interaction between stimulus presentation time, knob positions and interface layouts in terms of change detection accuracy. For the third and fourth images, there is no significant difference in stimulus presentation time at different knob positions and different interface layouts. In other words, there is no interaction between stimulus presentation time, knob positions and interface layouts in the change detection time. According to Fig. 5 and Fig. 6, there is no significant difference between knob position and interface layout in the keystroke accuracy and response time, that is, the two have no interaction in terms of the accuracy and time of change detection.

4.2 Analysis of eye movement index results.

4.2.1 Mean analysis

The average fixation duration can reflect the difficulty of information recognition in experimental tasks, and the number of fixation points can reflect the significance of information and efficiency of information search[22]. Based on these two eye movement indicators, the attention distribution of subjects under different influencing factors can be analyzed.

The experimental data of eye movement indicators of 30 subjects were summarized to obtain the mean and standard deviations of the overall average fixation time and average response time (unit: ms) of the subjects in different interface layouts, stimulus presentation times and knob positions, as shown in Table 7.

Table 7
Average fixation time and average number of fixation points, n = 30

Independent Dependent variable variable	Stimulus presentation time 250ms 350ms 450ms	Interface layout simple complex	Position area central edge
M Mean fixation time SD	2315.150 2220.267 2178.213 237.253 239.286 281.288	2139.465 2318.478 281.289 235.442	2108.465 2346.544 183.198 346.782
M Number of fixation points SD	31.250 29.872 26.324 4.362 4.128 4.654	28.524 30.628 4.263 4.453	27.865 31.426 4.332 4.255

As can be seen from Table 7, under the stimulation of different stimulus presentation times, different interface layouts and different knob positions, there is clear separation between the mean and standard deviation of the subjects' average fixation time and the number of fixation points. The basic trend is that: the shorter the stimulus presentation time of the image, the longer the average fixation time, which is longest at 450ms (M = 2178.213, SD = 281.288), 250ms (M = 2315.150, SD = 237.253), and 450ms (M = 26.324, SD = 4.654), and highest at 250ms (M = 31.250,SD = 4.362). The more complex the layout, the longer the average fixation time, and the more the fixation points. At the same time, it was found that the mean fixation time and the mean number of fixation points of different knob positions are clearly separated, and are significantly less in the central position than in the edge position.

In order to more clearly and intuitively establish the average fixation duration and the number of fixation points of each subject under different influencing factors, Origin software was used to make the plots presented in Fig. 5.

As can be seen from the figure above, due to individual differences, each subject produces different performances in the average fixation time and number of fixation points, but the overall trend is consistent. By observing the first and second images in Fig. 5, it is evident that the average fixation time of each subject gradually decreased and the number of fixation points gradually increased with the increase of the stimulus presentation time. The third and fourth images show that the average fixation time of each subject in the complex interface layout is generally higher than that in the simple interface layout, and the number of fixation points is also relatively higher. A closer look at the fifth and sixth images shows that compared with the edge position, the average fixation duration of the subjects in the central position is shorter and the number of fixation points is also smaller.

From the analysis of population mean and individual mean, it can be concluded that the stimulus presentation time, interface layout and position area all affect the participants' attention allocation. The shorter the stimulus time the more difficult the participants' information processing and recognition, and the lower the efficiency of information search. This difficulty is greater with a complex interface layout than with a simple interface layout, and the efficiency of information search is lower. The difficulty of information processing and identification in the central position area is lower than that in the edge position, and the information search efficiency is relatively higher.

4.2.2 Analysis of variance

Image presentation time (250ms/350ms/450ms), layout interface complexity (complex/simple), knob position (central position/edge position) were taken as independent variables, while average fixation time and number of fixation points were taken as dependent variables for ANOVA.

The homogeneity of variance test was applied to the average fixation time and number of fixation points of the subjects. The test results are shown in Table 8 and Table 9. The values of the average fixation time and number of fixation points were statistically significant ($P > 0.05$), and the data met the conditions of variance analysis.

Table 8
Test of homogeneity of variance for mean fixation time

Levin statistics	Degree of freedom 1	Degree of freedom 2	Significance
1.331	11	168	0.211

Table 9
Homogeneity of variance test for the number of fixations

Levin statistics	Degree of freedom 1	Degree of freedom 2	Significance
0.682	11	168	0.754
The results of ANOVA are shown in Table 9 and Table 10:			

Table 10
Analysis of variance for average fixation time

Variation source	Class III sum of squares	DOF	Mean squar-e	F	Significa-nce
Interface layout	387532.411	2	193766.206	3.620	.029
Stimulus time	706128.200	1	706128.200	13.191	.000
Position area	499701.422	1	499701.422	9.335	.003
Layout * Time	2649.900	2	1324.950	.025	.976
Layout * Position	16177.411	2	8088.706	.151	.860
Time * Position	728.022	1	728.022	.014	.907
Layout*Time*Position	18716.144	2	9358.072	.175	.840

Table 11
Analysis of variance for the number of fixation points

Variation source	Class III sum of squares	DOF	Mean squar-e	F	Significa-nce
Interface layout	276.744	2	138.372	9.103	.000
Stimulus time	158.672	1	158.672	10.438	.001
Position area	764.672	1	764.672	50.305	.000
Layout * Time	.544	2	.272	.018	.982
Layout * Position	3.011	2	1.506	.099	.906
Time * Position	.939	1	.939	.062	.804
Layout*Time*Position	.011	2	.006	.000	1.000

By observing Table 10 and Table 11, we can see that the stimulus presentation time, interface layout, and knob position all showed significant effects ($P < 0.05$) on the average fixation time and the number of fixation points ($P < 0.05$). Different interface layouts and different knob positions have significant differences in the average fixation time and the number of fixation points, and there is no interaction between the three ($P > 0.05$).The LSD test was used to conduct multiple comparison of the difference of average fixation time and number of fixation points corresponding to different stimulus presentation times.

Table 12
Multiple comparison analysis table of average fixation time and number of fixation points

	(I)Time	(J)Time	Significance(Mean fixation time)	Significance(Number of fixation points)
LSD	250	350	.062	.022
		450	.010	.000
	350	250	.062	.022
		450	.459	.054
	450	250	.010	.000
		350	.459	.054

Multiple comparisons in Table 12 showed that there was significant difference in average fixation time between 250ms and 450ms ($P < 0.05$), but there was no significant difference among 350ms, 250ms and 450ms ($P > 0.05$). There were significant differences in the number of fixation points among 250ms and 350ms and 450ms ($P < 0.05$), but there was no significant difference between 350ms and 450ms ($P > 0.05$).

In order to further intuitively compare the interaction among the three on average fixation time and the number of fixation points, Origin was adopted to create the interaction diagrams shown in Fig. 6.

By observing the first and second images in Fig. 6, it can be seen that there is no significant difference in the average fixation time of stimulus presentation of different knob positions and interface layouts. In other words, there is no interaction between stimulus presentation time, knob positions and interface layouts in the processing and recognition of information. The third and fourth images show there was no significant difference between the number of fixation points and the stimulus presentation time of different knob positions and interface layouts. In other words, there was no interaction between the stimulus presentation time and the knob positions and interface layouts in terms of efficiency of information search. According to Fig. 5 and Fig. 6, there is no significant difference between knob positions and interface layouts in the average fixation time and number of fixation points; that is, the two have no interaction effect on the efficiency of information processing recognition and variable information search.

4.3 Comprehensive Discussion

(1) Discussion on the effect of stimulus presentation time on change blindness

Simons[23] once proposed the covering hypothesis, pointing out that change blindness when observing an object may be caused by the inability of people to process and compare the information of the object before and after the change, meaning a complete coherent representation is not be formed. This study found that increasing stimulus presentation would improve the efficiency of change detection, as well as efficiency of information search, processing and recognition. These results indicate that appropriate extension of the participants' fixation time is beneficial to the participants' processing and comparison of the complete information of the objects before and after the change, thereby improving the efficiency of change detection, to promote the formation of a complete and coherent representation of the object in the brain, and reduce the probability of change blindness.

(2) Discussion on the effect of interface layout on change blindness

The higher the complexity of the object is, the more information the subject will need to process, meaning the cognitive load of the subject will be high, which could make it more likely for the subject to fail to detect the change of the object [24]. As can be seen from the above analysis results, the complexity of the interface layout may, to a certain extent, increase the cognitive load of the subject. As a result, the participants’ efficiency of target information search and change detection will be reduced, causing the participants to turn a “blind eye” on change of object information before and after the presentation, which can increase the incidence of change blindness.

(3) Discussion on the influence of knob position on change blindness

The position of objects has always been an important influencing factor of change blindness. Many researchers have proved that people tend to have more comprehensive information recognition processing and better performance in change detection in the central area of the visual field [25]. Analysis of the experimental results revealed that the change detection efficiency and information search efficiency of the center position knob are better than that of the edge position knob. The reason may be that people are accustomed to devote more attention to the central area, thus object information processing and change detection performance in the central area is more efficient than in the edge area. Therefore, the probability of change blindness occurring in the central area is relatively lower.

(4) Discussion on the effects of stimulus presentation time, interface layout and knob position on change blindness have been discussed

Through the above analysis, it can be concluded that there is no interaction among the three factors. According to the multi-resource theory [26], the influences of different factors are superimposed on each other rather than interacting with each other.

5. Conclusion

(1) The stimulus presentation time had a significant effect on the change blindness phenomenon in the field of civil aviation, that is, with the increase of stimulus presentation time, the change detection performance of the subjects also improved. In the field of civil aviation, pilots need to monitor the information changes of the surrounding environment in real time. If the stimulus presentation time is too short, it could negatively affect a pilot’s information resource processing efficiency, resulting in change

blindness. Therefore, the prompt time for some important safety information prompt should be extended as long as possible.

(2) The complexity of the knob interface layout has a significant effect on change blindness, that is, the more complex the knob interface layout is, the more resources and energy the subjects need to utilize in identifying information, which could reduce a pilot's efficiency of change detection. In the field of civil aviation, the design of panel interface layout should thus be as simple and reasonable as possible to facilitate recognition and reduction of the cognitive load of aircraft pilots.

(3) The knob position in different areas also had a significant effect on change blindness, that is, in a visual field, subjects tend to pay more attention to the central knob. As a result, change detection performance in the central position is better than in the edge position. Therefore, pilots should pay more attention to the stimulus changes of the edge position of the panel during a flight.

(4) It has been found that there is no interaction among stimulus presentation time, interface layout and knob position.

Declarations

Data availability

The data used to support the findings of this study are available from the corresponding author upon request.

Competing interests

The authors declare no competing interests.

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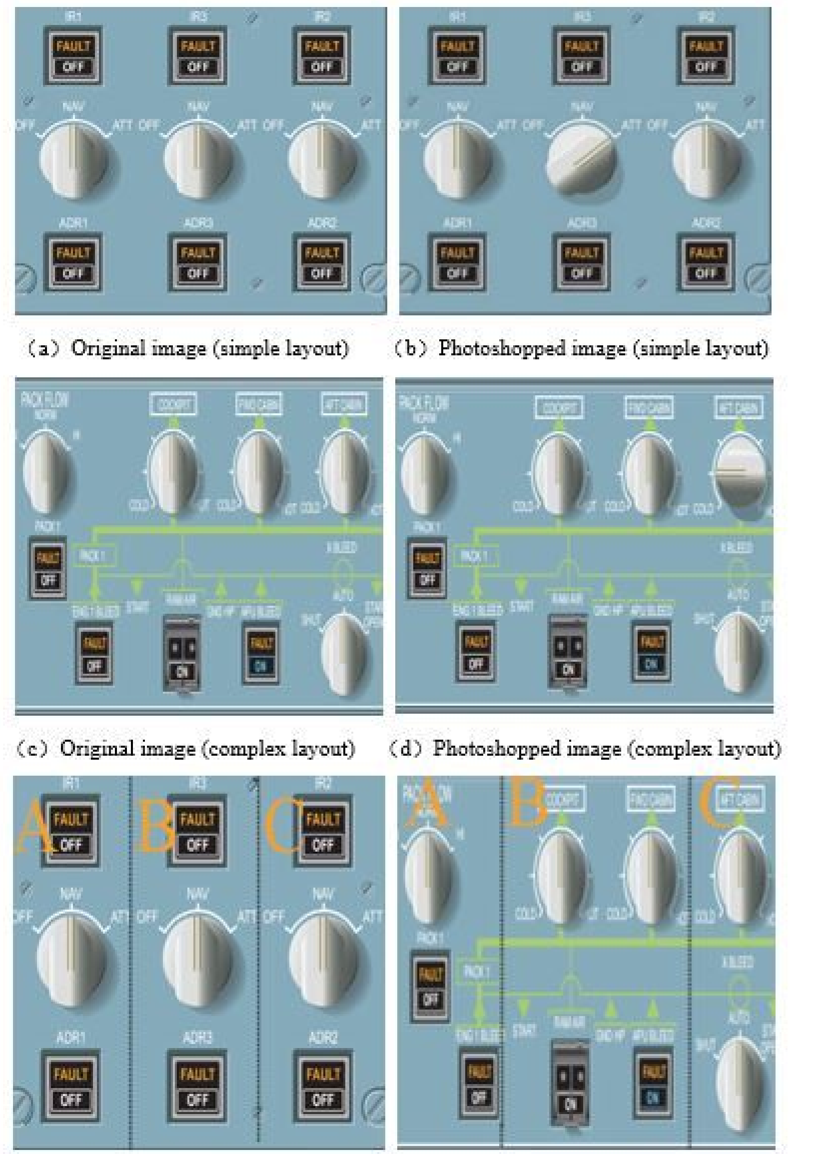
References

1. Rensink R A, O'Regan J K, Clark J J. To see or not to see: the need for attention to perceive changes in scenes[J]. Psychological Science, 1997, 8(5): 368–373.
2. Liu Y, Liu Y, Liu Y, et al. The effects of change blindness on the cognitive performance of college students [J]. Tianjin normal university, 2021. DOI: 10.27363 /, dc nki. Gtsfu. 2021.000005.

3. Filtness A J, Beanland V, Miller K A, et al. Sleep loss and change detection in simulated driving[J]. Chronobiology International, 2020, 37(9–10):1–11.
4. Zhao Aoxue, Zhuang Qialing, Ma Guojie. Drivers' vision blindness in trafficscenarios and its implications [J]. Applied psychology, 2020,26 (02):129–139.
5. Galpin A, Underwood G, D Crundall. Change blindness in driving scenes[J]. Transportation Research Part F Traffic Psychology & Behaviour, 2009, 12(2):179–185.
6. Beanland V, Ashleigh J. Filtness, Jeans R. Change detection in urban and rural driving scenes:effects of target type and safety relevance on change blindness[J]. Accident Analysis andPrevention, 2017, 100: 111–122.
7. Beanland V, Hansen L J. Do cyclists make better drivers? Associations between cycling experience and change detection in road scenes[J]. Accid Anal Prev, 2017, 106(sep.):420–427.
8. Zhao N, Chen W, Xuan Y, et al. Drivers' and non-drivers' performance in a change detection task with static driving scenes: is there a benefit of experience?[J]. ERGONOMICS, 2014, 57(7):998–1007.
9. Mayo S A. Change Blindness in the Synthetic Vision Primary Flight Display: Comparing Eye Tracking Patterns with Pilot Attention[J]. 2009.
10. Ahlstrom U, Suss J. Change blindness in pilot perception of METAR symbology[J]. International Journal of Industrial Ergonomics, 2015, 46:44–58.
11. Yang Y, Zheng X, Easa S, et al. Effect of Simultaneous Emotions and Driving Tasks on Driver's Change Blindness[J]. OALib Journal, 2014, 01(5):1–8.
12. Filtness A J, Beanland V, Miller K A, et al. Sleep loss and change detection in simulated driving[J]. Chronobiology International, 2020, 37(9–10):1–11.
13. Murphy G, Greene C M. High perceptual load causes inattentional blindness and deafness in drivers[J]. Visual Cognition, 2015, 23(7):810–814.
14. Crundall D, Howard A, Young A. Perceptual training to increase drivers’ ability to spot motorcycles at T-junctions[J]. Transportation research part F: traffic psychology and behaviour, 2017, 48: 1–12.
15. Zárate D. The effects of expertise and information position on change blindness detection within an aviation domain[J]. 2012.
16. McDermott Ealding C, Stedmon A. Now You See It, Now You Don’t: A Change Blindness Assessment of Flight Display Complexity and Pilot Performance[C]//International Conference on Engineering Psychology and Cognitive Ergonomics. Springer, Cham, 2018: 637–648.
17. Andrighetto L, Bracco F, Chiorri C, et al. Now you see me, now you don’t: Detecting sexual objectification through a change blindness paradigm[J]. Cognitive Processing, 2019, 20(4): 419–429.
18. Li Jing, Yu Shulan, Liu Wei. Journal of computer-aided design & computer graphics,2017,29(07):1334–1342.
19. Zhang Hanyan. An eye movement study of visual cognitive Processing in change blindness [D]. East China Normal University,2017.

20. Jin Huibin, Hu Zhanyao, Yu Osmanthus. Journal of Chongqing Jiaotong University (Natural Science edition), 201,40(04):1–5 + 18.
21. Herbranson W T. A Method for Investigating Change Blindness in Pigeons (Columba Livia)[J]. JoVE (Journal of Visualized Experiments), 2018 (139): e56677.
22. Hochhauser M, Aran A, Grynszpan O. Investigating attention in young adults with autism spectrum disorder (ASD) using change blindness and eye tracking[J]. Research in Autism Spectrum Disorders, 2021, 84: 101771.
23. Simons D J, Rensink R A. Change blindness, representations, and consciousness: Reply to Noë[J]. Trends in Cognitive Sciences, 2005, 9(5): 219.
24. Beanland V, Ashleigh J. Filtness, Jeans R. Change detection in urban and rural driving scenes:effects of target type and safety relevance on change blindness[J]. Accident Analysis andPrevention, 2017, 100: 111–122.
25. D'Addario P, Donmez B. The effect of cognitive distraction on perception-response time to unexpected abrupt and gradually onset roadway hazards[J]. Accident Analysis & Prevention, 2019, 127: 177–185.
26. Smith R E, Buchholz L M. Multiple resource theory and consumer processing of broadcast advertisements: An involvement perspective[J]. Journal of Advertising, 1991, 20(3): 1–7.

Figures



（a） Original image (simple layout)　（b） Photoshopped image (simple layout)

（c） Original image (complex layout)　（d） Photoshopped image (complex layout)

（e）Position area division map (simple layout)（f）Position area division map (complex layout)

Figure 1

Sample experimental image (A and C are edge position, B is central position)

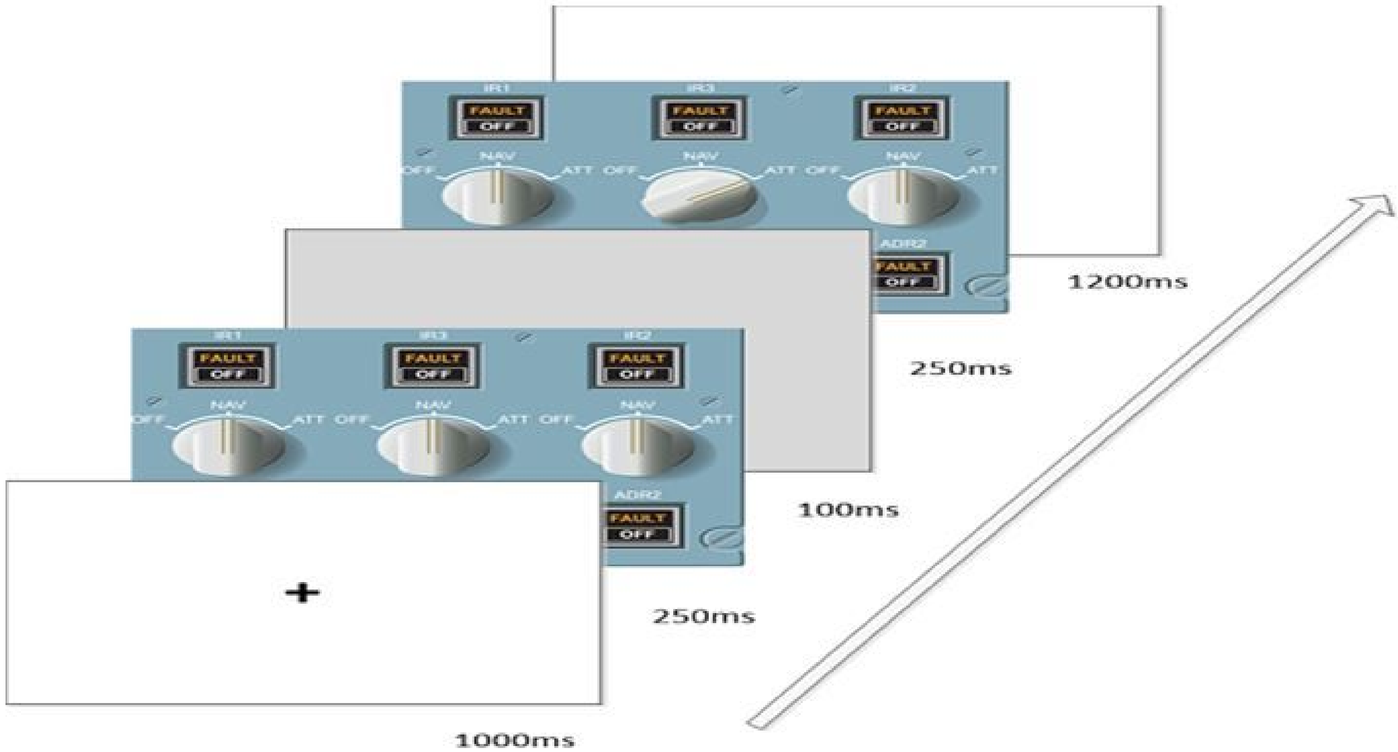
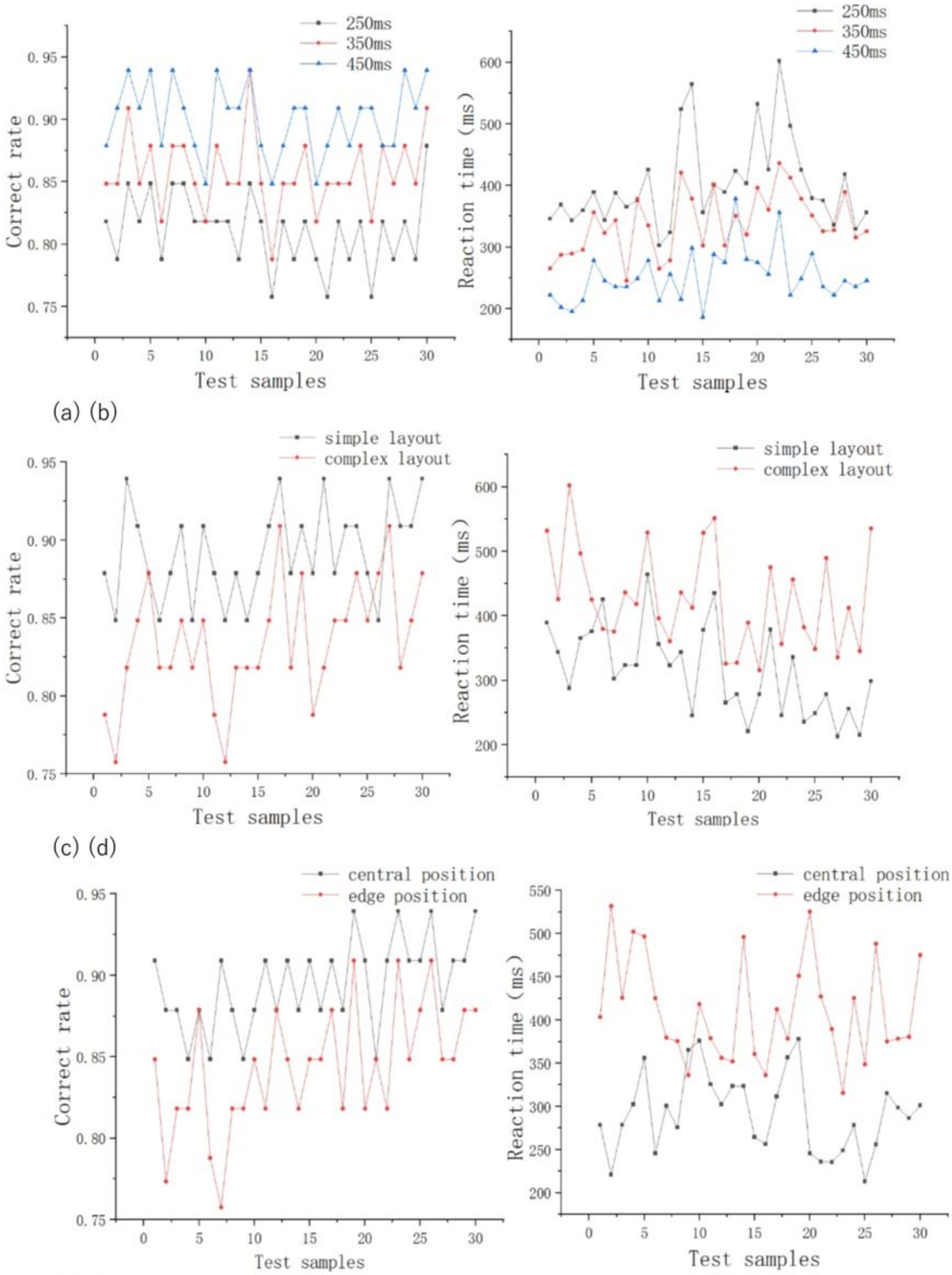


Figure 2

Schematic diagram of the experimental flow



(a) (b)

(c) (d)

(e) (f)

Figure 3

Average accuracy and response time of each subject in different stimulus presentation times, interface layouts and position areas

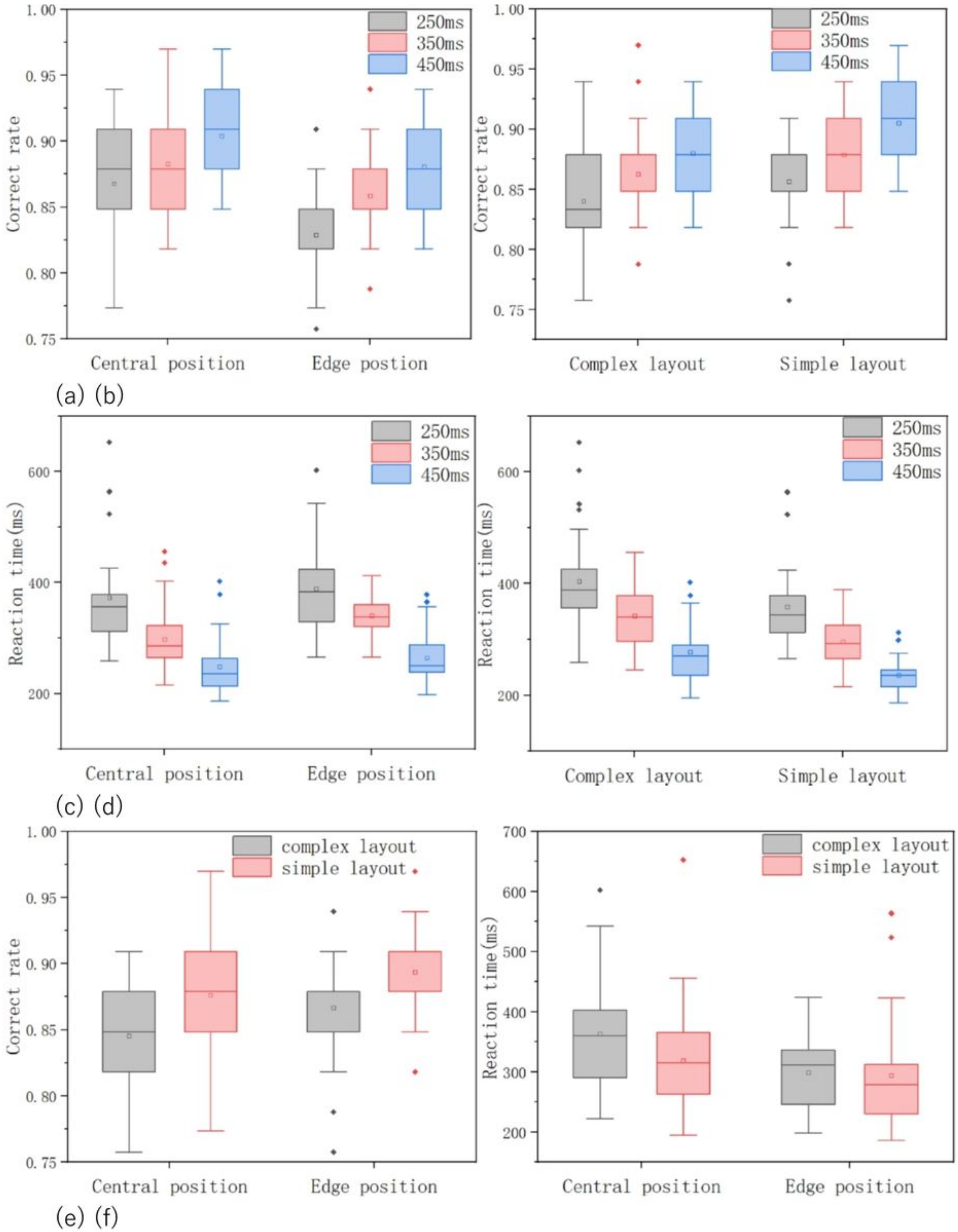


Figure 4

Interaction diagrams of stimulus presentation times, interface layouts and knob positions on behavioral indicators

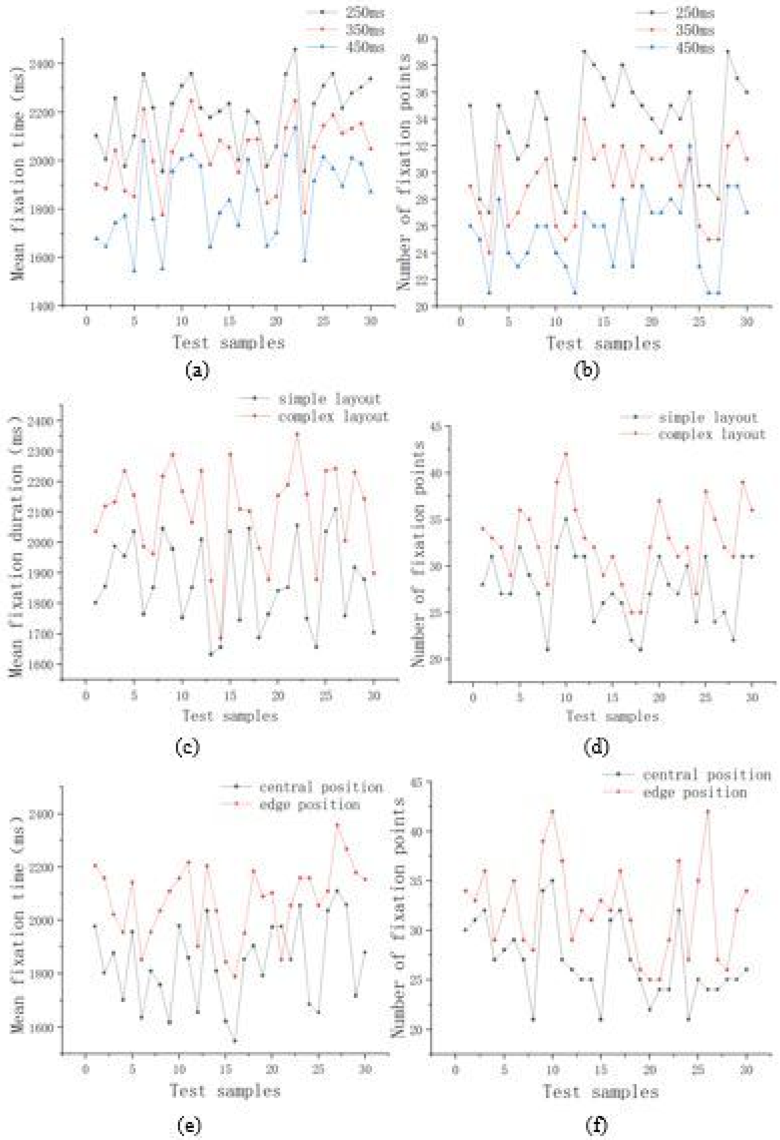


Figure 5

Average fixation time and number of fixation points of each subject under different stimulus presentation times, interface layouts and knob positions

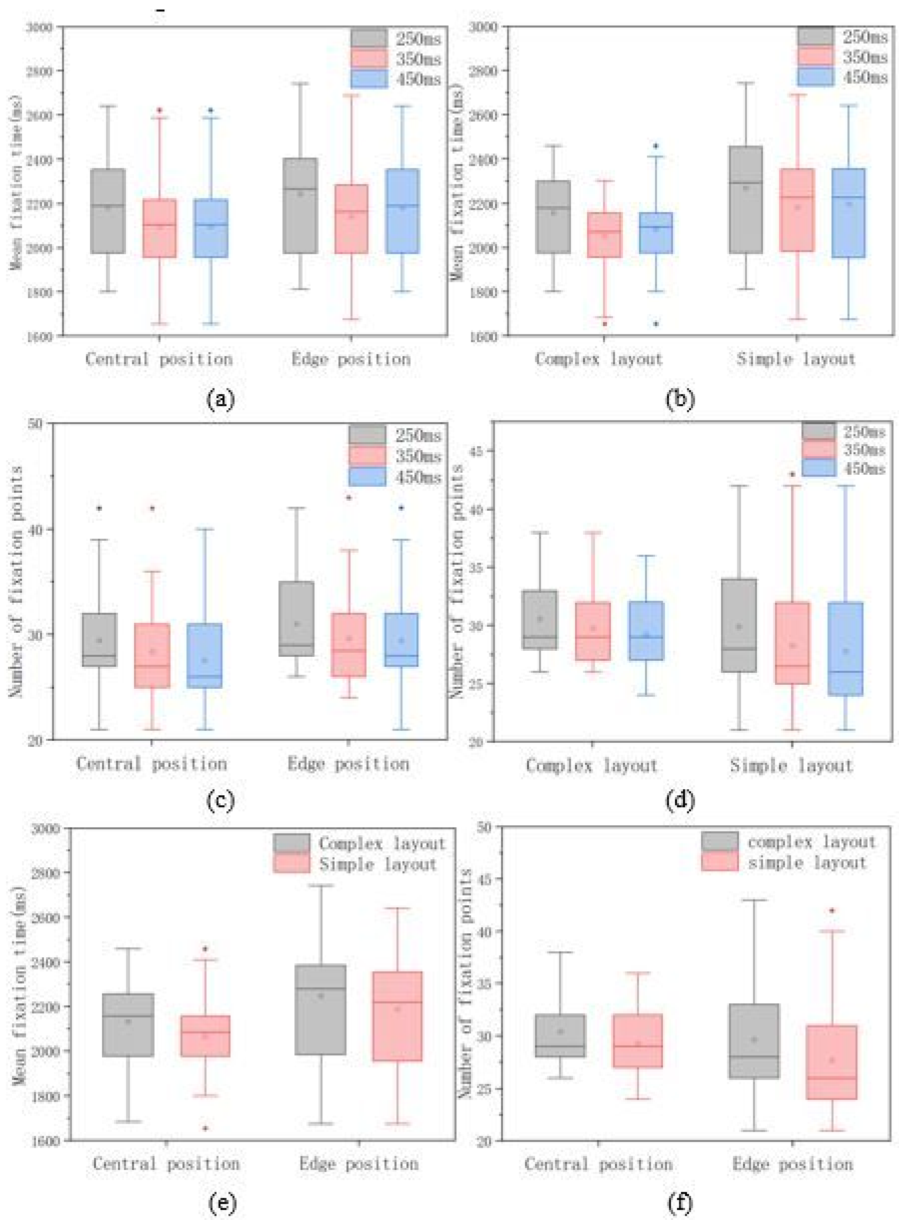


Figure 6

Interaction of stimulus presentation time, interface layout and knob position on eye movement index