A Study of the Impact of Interface Colour Schemes and Work Experience on Visual Search Performance

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Abstract. Visual search of thermal power plant system is very important in practical work, so the influence of interface color scheme on visual search performance is studied Through designing two factor experiment, we decide to test the visual search influence and the level of visual fatigue under whether the The experimental data were processed by repeated measure analysis of The results showed that when the color scheme was white against black, the subjects showed the highest accuracy and the shortest response time. In addition, the experienced group had higher search performance than the inexperienced group, and was less prone. The experimental results can provide reference for the research on the influence of interface color scheme on visual search performance. The experimental results can provide reference for the research on the influence of interface color scheme on visual search performance.

Keywords: Interface color scheme · Visual search efficiency · Visual fatigue

1 Introduction

As the main channel for information transfer between people and electronic programmes, interfaces are used in a wide range of life and work activities, for example in thermal power plants, where a large number of interfaces are used, and where the existing interfaces are generally mixed-colour designs, the complex colour and information distribution can lead to some visual attention problems. For example, the visual fatigue caused by prolonged operation can lead to misjudgements by the interface operator. A humanised interface design can make the system interface more user-friendly and effectively improve user interaction with the interface, so it is essential to optimise the design of the boundary colour scheme.

As early as the beginning of the 20th century, colour as a visual element in interface design was identified as an important factor in the presentation of graphic information. Through the use of colour, interfaces can be segmented, which can better highlight the presentation of effective information in the interface and accurately guide the user through actions and judgements. Colour can be used to improve the efficiency of target

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display [1, 2] and, when used appropriately, to respond correctly to the target with faster search times [1]. For example, Murch recommends avoiding the use of blue in text, but Matthews, Lovaslk et al. [3] suggest that red and blue, either alone or in combination, can have a significant effect on the efficiency of searching for targets [4]. A good choice of colour will improve performance, increase user productivity and accuracy, and have a positive effect on reducing user cognitive load.

Research into the effect of colour on visual search efficiency in the context of an interface began as early as the 1950s. Under static conditions, the colour scheme of an interface can significantly affect visual search performance. Colour is known to have a significant impact on attention deployment and eye movement trajectories. As visual processing power is limited and attention is required to confirm the presence of a particular object, the choice of colour is crucial as a 'guiding' feature in visual search or as a 'salient' feature captured in a saliency map. 42 studies published between 1952 and 1973 on the role of colour in visual display search tasks. The results show that in some cases the judicious use of colour can have a significant positive impact. For example, colour schemes affect the recognisability of information and the visual performance of iconographic tasks on the display, with sensible colour schemes improving performance. Inappropriate colours can reduce performance and increase discomfort and the likelihood of visual fatigue. For example, Matthews reports that red on a black monitor takes significantly less time to search than green on a black monitor. Some studies have shown that primary colours of red, green, blue and yellow are more significant than non-primary colours [5]. It has also been suggested that using one increases the visual impact of the interface by increasing the contrast between the background and the text [1, 6]; for example, white text may stand out when placed on a purple background. The research by Wu and Pastoor [7] similarly demonstrates that in practice different colour combinations can have a different impact on the search efficiency of important targets. Using these colours as background and foreground (font) colours in practical applications allows users to perceive text more easily through clear differential contrast, thus enhancing visual search compared to other colour combinations. Furthermore, by studying 18 graphical user interfaces with different colour attributes, Wu and Chen showed that the right mix of colours was one of the most important factors influencing subjects' visual search performance.

Similarly, poor use of colour can lead to reduced performance [8, 9]. Many scholars have shown that it is important not to complicate the colour palette in a graphical interface as it can have a psychological and physiological impact on the user, leading to discomfort [2, 5]. For example, red text stands out when placed on a green background, but can easily cause visual fatigue. The use of colour as background and foreground (font) colour in an interface therefore requires both that the user perceives the text more easily through the obvious differences in contrast, and that the colour tones are harmonious and chosen in a combination that enhances visual search. The use of colour in visual displays, particularly in interfaces, should be influenced not only by the subjective preferences of the designer or user, but also by the cognitive/perceptual constraints of the user. Poor colour choices can reduce performance and increase the likelihood of visual fatigue [10, 11].

Since the 1980s, the study of work experience has become an important issue of interest to researchers. Most scholars now believe that work experience affects performance by influencing the formation of tacit knowledge [12]. Sternberg [13] defines tacit knowledge as "knowledge that is behaviourally directed; acquired without the direct help of others; and acquired by individuals in order to achieve a valuable goal". 1987 found that the core component of [14] work experience is not only its quantitative component, but also the content of the qualitative component of work experience. These findings are evidence of the high conceptual validity of the concept of integration of work experience. Some studies have confirmed that practical and work-related knowledge and skills developed through work experience play a greater role than general cognitive abilities in influencing performance [15].

In summary, there is a lack of research on the impact of colour schemes and work experience on visual search performance in large complex interfaces. This study is intended to simulate the operation of a large complex monitoring interface system to assess the impact of different colour schemes and work experience on visual search performance, which will have some reference significance for the design and use of colour schemes in large complex interfaces.

2 Object Methods

2.1 Subjects

The experiment recruited 40 subjects, 20 in the inexperienced group were students at Liaoning University of Engineering and Technology, with an average age of 24.2 years old and half of each gender. The experienced group consisted of 20 technicians from a Beijing thermal power company, with an average age of 33.4 years old and half of each gender. All subjects had good visual acuity status.

2.2 Experimental Design and Variables

A mixed within-group design was used for this experiment. The intra-group factor is the colour scheme (8 types: white target on black, cyan target on black, yellow target on blue, red target on blue, cyan target on yellow, purple target on yellow, black target on white, red target on white) and the colour scheme is selected from the eight colour schemes provided by the International Commission on Illumination. The inter-group factor is experience, (divided into two groups: experienced and inexperienced), with five years of work being considered experienced.

Experimentally measured usability metrics include visual search performance (visual search time and correct rate) and visual fatigue. Visual search performance was measured using E-prime software, a computerised experiment design, generation and operation software for psychological and behavioural experiments, which effectively records the reaction time and results of subjects to a variety of stimuli such as sounds and pictures. The reaction time taken by the subject to search for key information in the search screen and then press f to switch to the judgement screen is the visual search time; the percentage of correct identification of the target in the search screen is the percentage of correctness, and there are only two types of single correctness: 100% and 0. Subjects completed a visual fatigue questionnaire after each task based on their subjective experience during the experiment, and the level of visual fatigue was determined based on the results of the subjects (three types: mild visual fatigue, moderate visual fatigue and severe visual fatigue). The options on the visual fatigue questionnaire were given different scores, and the sum of the options ticked by the subject reflected the subject's visual fatigue. 0–33 was classified as mild visual fatigue, 34–67 as moderate visual fatigue and 68–100 as severe visual fatigue.

2.3 Experimental Materials and Tasks

This experiment uses Axure software to draw the interface for the experimental task. The visual search experimental task program was prepared using e-prime software and presented through a 15.6″, 1400 x 1050 resolution Dell laptop. The information objects presented in the interface all simulate the information objects of the actual thermal plant interface and are of essentially the same type.

The subject has to search for and match information to the target according to the search guide. At the start of the task, the search guide is displayed on the screen and the subject reads it and presses the f key to jump to the search screen. The subject was asked to find the target to be searched as quickly as possible (the visual search interface is shown in Fig. 1). When the target information was found, the participant immediately pressed the f key and the interface jumped to the information matching interface where the participant was asked to select exactly the option that matched the target information they saw before moving on to the next search task. After experimenting with different scenarios of the same colour scheme, the participant completes a visual fatigue questionnaire. The colour preference questionnaire was completed after all experiments were completed.

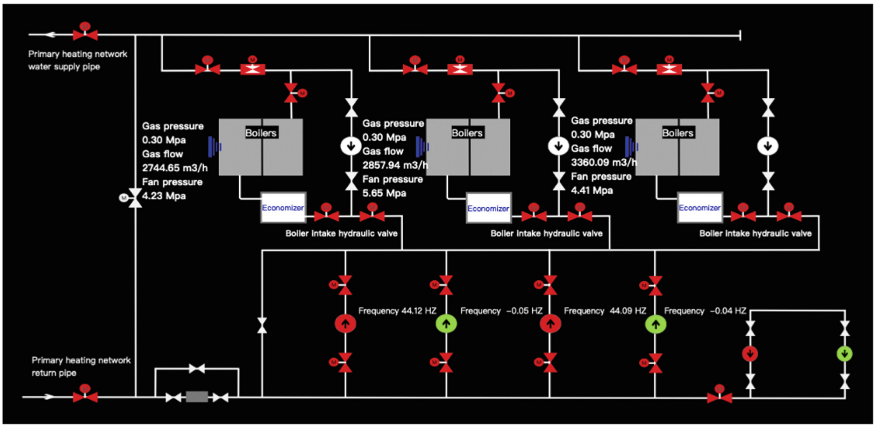


Fig. 1. Experimental search interface

2.4 Experimental Procedure

Before the start of the experiment, the subject introduces the purpose of the experiment to the participant, the subject reads the experiment information sheet and completes the basic information, followed by a mock experiment (similar to the actual experiment). After the mock experiment, the formal experiment began. Participants were asked to complete a series of visual search tasks for each colour scheme as quickly and accurately as possible. The visual search tasks were the same for each colour scheme, and the sequence was based on searching for target information according to the search guide followed by information matching. The visual search task was repeated eight times for each colour scheme and the time and accuracy of the visual search was automatically recorded by E-prime software. After completing the experiment with different scenarios of the same colour scheme, the participant completed a visual fatigue questionnaire and took a five-minute break. After the visual search experiment was completed for all eight colour schemes, the participant filled in the subjective colour preference questionnaire and the subject checked the experiment data.

2.5 Data Analysis

This experiment used repeated measures ANOVA to analyse the effect of interface colour scheme and work experience on visual search performance and visual fatigue. Data were analysed using SPSS22.

3 Results

Tables 1 and 2 show the effects of interface colour scheme and work experience on the completion time and correctness of the visual search task, respectively.

3.1 The Impact of Interface Colour Schemes on Visual Search Performance

The interface colour scheme had a significant effect on the visual search time for the target task ($F(7, 42) = 4.782$, $p = 0.012$), but not on the correct response rate to the target ($F(7, 38) = 2.416$, $p = 0.253$). The subjects' search time for the target varied across the different colour schemes, with the data showing that when the contrast between the background and text colour of the test interface was extremely pronounced (white on black, black on white), the subjects' search time was shorter, while when the contrast between the background and text colour of the test interface was not pronounced (cyan on yellow, yellow on blue), it took longer. In terms of correctness, each different colour scheme did not have much impact on the correct response rate of the target. According to the data in Table 2, when the colour scheme of the interface was chosen as white on black or black on white, the correctness rate was slightly higher, but there was no statistically significant difference compared to the other colours.

Table 1. Effect of colour scheme and relevant work experience on search time for targets

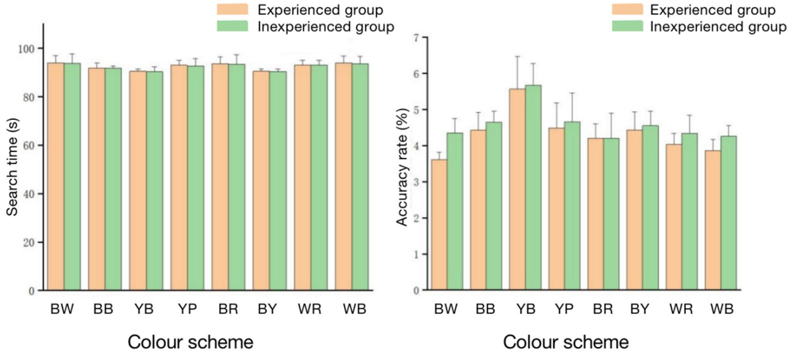
	Average value	Standard deviation	F-value	P-value
Colour schemes				
Black and White	3.817	0.331	4.782	0.012
Black and blue	4.425	0.219		
Huang Qing	5.565	0.153		
Yellow Purple	4.487	0.122		
Blue and red	4.201	0.513		
Blue and yellow	4.434	0.634		
White and red	4.096	0.383		
White and Black	4.023	0.485		
Work experience				
Experienced	4.353	0.246	3.481	0.045
No experience	4.981	0.351		

Table 2. Effect of colour scheme and associated empirical targets on correct response rate of correct response

	Average value	Standard deviation	F-value	P-value
Colour schemes				
Black and White	93.97	16.3	2.416	0.253
Black and blue	91.83	20.4		
Huang Qing	90.37	21.3		
Yellow Purple	92.98	15.4		
Blue and red	93.45	17.2		
Blue and yellow	90.43	28.5		
White and red	93.05	21.4		
White and Black	93.66	19.9		
Work experience				
Experienced	92.02	20.96	1.263	0.358
No experience	91.81	23.46		

3.2 The Impact of Work Experience on Visual Search Performance

Work experience had a significant effect on visual search time for the target task ($F(1, 22) = 3.418$, $p = 0.045$), while the effect on correctness was not significant. The data showed that the experienced experimental group tested had a shorter search time for the



(a) Interaction of interface colour matching and work experience on visual search completion time

(b) Interaction of interface colour matching and work experience on accuracy

Fig. 2. Interaction between colour scheme and work experience in a visual search task

target than the inexperienced test group, but there was no significant difference in their correct rate, and some inexperienced testers could achieve a 100% correct rate.

3.3 Interaction of Interface Colour Scheme and Work Experience on Visual Search Performance

Figure 2 shows the interaction performance of colour scheme and work experience in the visual search task. There was a significant interaction between colour scheme and work experience on visual search task completion time ($F(2.914, 42.787) = 8.194$, $p < 0.001$), but no interaction on correctness on the visual search task ($F(2, 46) = 1.263$, $p = 0.358$).

3.4 Visual Fatigue

According to the data results in Table 3, the experienced group was less likely to feel visual fatigue (mild) for the white on black or black on white colour scheme, while for the yellow-cyan colour scheme, the subjects were basically in a state of severe visual fatigue; the inexperienced group also showed a state of severe visual fatigue for the yellow-cyan colour scheme, and the black on white colour scheme was less likely to cause them a state of fatigue. In addition, the statistics show that the experienced group was less likely to experience visual fatigue than the inexperienced group.

3.5 Subjective Colour Preferences

According to the results in Fig. 3 and Table 4, both the experienced and inexperienced groups preferred the black on white colour scheme, while the cyan on yellow and purple on yellow colour schemes were not chosen.

Table 3. Visual fatigue test scores

	Black and White	Black and Blue	Huang Qing	Yellow Purple	Blue and Red	Blue and Yellow	White and Red	White and Black	Average
Experienced	20.21	30.23	77.33	41.21	36.11	57.15	27.12	22.11	38.43
No experience	22.35	40.17	82.56	52.45	33.45	72.19	29.95	19.52	42.08

(0–33 is classified as mild visual fatigue, 34–67 as moderate visual fatigue, 68–100 as severe visual fatigue).

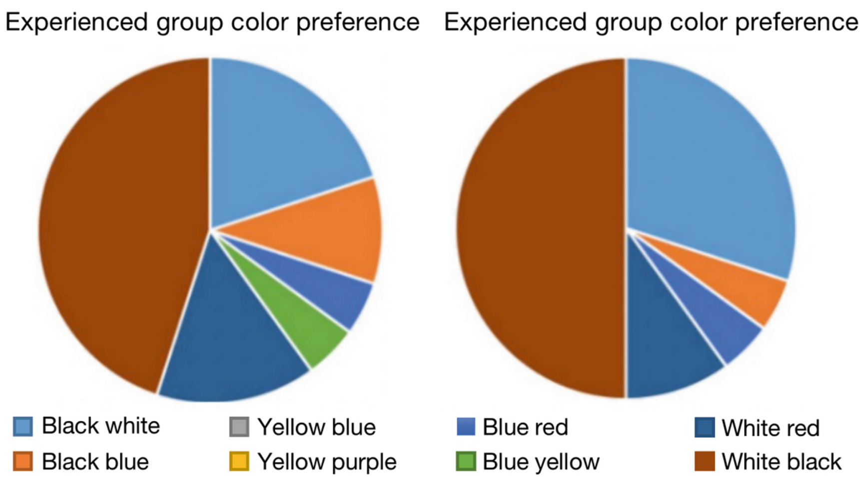


Fig. 3. Comparison of colour preferences with and without the experience group

Table 4. Subjective colour preferences

	Black and White	Black and Blue	Huang Qing	Yellow Purple	Blue and Red	Blue and Yellow	White and Red	White and Black
Experienced	20%	10%	0	0	5%	5%	15%	45%
No experience	30%	5%	0	0	5%	0	10%	50%

4 Discussion

This paper assesses the impact of different colour matching environments and the availability of work experience of the subjects on visual search performance by simulating a situation in which the monitoring interface system of a heat source plant is operated.

The experimental results show that the interface colour scheme has a significant effect on visual search time in visual search performance. This finding suggests that individuals produce different visual search performance when faced with different colour schemes. This is similar to the findings of Jelmer's study on the effect of background on visual search. When there was a significant difference in the brightness of the background colour and the target information colour, there was a significant reduction in the time taken by the testers to correctly grasp the information. For this experiment, both the black-on-white and the white-on-black colour schemes produce a strong visual contrast when the operator navigates the interface. Black and white, as polar colours, are the standard for measuring the lightness and darkness of other colours, and this strong colour contrast has a positive effect on the subject's ability to grasp key information. This contrasting colour scheme is more likely to attract attention and help the subject to identify information, while the subject's visual experience is more comfortable. The yellow-cyan colour scheme in the experimental task, with its small colour difference and little difference in lightness and darkness, seriously reduces the efficiency of the subject's search for the target information and increases visual fatigue.

The data showed that the presence or absence of experience had a significant effect on the search time for the visual search task and no significant effect on the correctness rate. The experienced group took less time to search for target information than the inexperienced group, which is in line with our expectations. For the experienced group, who were familiar with the interface, the location of key information was faster and more accurate than for the inexperienced group. For the inexperienced group, the interface was more complex and could not be mastered during the test time, so they were unable to search for key information in blocks and spent more time looking at the simulated interface map. The inexperienced group therefore had significantly higher levels of visual fatigue. Possible reasons for the lack of significant differences in correctness are that the experienced group was more familiar with the simulated interface map and spent less time observing the target interface, which could have led to a lack of careful observation of certain search targets and consequently to errors, or even to a decrease in correctness due to their own subjective experience. However, on balance, the visual search performance of the experienced group was higher than that of the inexperienced group.

We found that when the interface colour scheme was chosen to be black on white or white on black, all subjects showed optimal results in terms of search time as well as correctness. Based on the ideas in this paper, it can be extended to large factories in China with the same type of interface, where the choice of interface colour scheme with a clear contrast helps to improve the performance of the technicians involved, and in longer working hours, the interface with such a colour scheme is less likely to cause visual fatigue and protect the technicians' eye health.

This study also has some limitations in the experimental part. The first aspect is that the diagnosis and evaluation of visual fatigue were based on subjective questionnaires, which measure results that can be influenced by subjective consciousness, and the evaluation results were generated by the personal understanding of different subjects, so individual cognitive differences may contribute to inaccurate evaluation results.

Furthermore, although there may be individual differences in the assessment of the aesthetic qualities of particular colours or colour combinations, these preferences may not be relevant to task performance. In the second aspect, different colour schemes did show differences in the effects of visual search performance and visual fatigue, but the brightness of the colour scheme and the illumination of the operating environment have not yet been taken into account, an issue that we will explore further in the future.

5 Conclusion

This study provides new insights into the design of large-scale interfaces in China by assessing the effects of two factors (interface colour scheme and work experience) on visual search performance and visual fatigue. The experimental results show that interface colour scheme has a significant effect on visual search performance, while work experience has a significant effect on the duration of visual search. Future research could delve into the design of interface colour schemes and their application options by adjusting colour shading, using diverse samples, and increasing eye-movement experiments.

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