Evaluation of Indicative Symbol Coding for Fighter Cockpit HUD Based on Different Environmental Background

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ABSTRACT

Head-up display (HUD) is an important medium for fighter pilots to obtain the flight status and flight parameters of aircraft. In this paper, the cognitive human-computer interaction process of pilots when using HUD to search information is analyzed, two groups of reaction time measurement experiments are carried out, and the statistical analysis method is used to study the pilot's cognitive speed of HUD interface. The results show that the application of box arrow is better for the application of HUD interface under different environmental conditions, and the accuracy is high, but the integrity is slightly lower than that of open arrow and closed arrow. This paper provides theoretical support for the improvement of fighter HUD display interface.

Keywords: Information Hierarchy, Visual Interaction, Symbolic Features, Cognitive Efficiency

INTRODUCTION

Head-up display (HUD) based on augmented reality technology solves the internal and external visual contradiction of pilots frequently observing cockpit instruments and flight tracks alternately during flight operation (Xu, 1996).

At present, there have been a lot of researches on HUD interface design at home and abroad. Xu Xiao studied the visual coding of the cockpit interface display design (Xu, 2014). Blundell studied the color-coding of HUD flight symbols in the real flight environment (Blundell, 2020). Innes believes that the symbols in the interface interact with the environment to adjust the flight workload (Innes, 2019). Stanton considered that the display symbol is beneficial to the pilot's operation (Stanton, 2019).

Under different background conditions, through the design of different indicator symbols, taking the flight altitude and speed of fighter HUD as indicators, this study explores its impact on the driver's information reading efficiency.

The visual coding of the cockpit HUD display interface has less research on symbols. Therefore, the following hypotheses are proposed:

1) Different indicative symbols will affect the pilot’s reaction time and operational efficiency;

2) Different flight backgrounds will affect the pilot's reaction time and operational efficiency.

EXPERIMENTAL METHOD

Experimental Preparation

According to the national standard <GJB 300-1987 aircraft head up display characters>, combined with relevant research, three indicator symbols are selected: open arrow, closed arrow and box arrow (see Figure 2.1 a. b. c.). The experiment selects speed, altitude information and different values as the readable information of the HUD interface, and uses black as the background for material design to get 9 sets of pictures.

Experiment selects three different backgrounds in the flight state (see Figure 2.2 a. b. c.), which are the day sky, the evening sunset, and the day ground. Then using different background conditions and three indicative symbols as variables for material design, 9 sets of pictures were obtained.

(a) (b) (c)

Figure 2.1 Three indicative symbol representations

(a) (b) (c)

Figure 2.2 Three background condition pictures

The experiment is divided into pre-experiment and formal experiment. The pre-experiment takes the black blank control group as the background, changes the data information in the interface information, and uses 3*3 (indicative symbol*data information group) repeated measurement design to collect reaction time and accuracy data. The formal experiment uses the same data information, using 3*3 (indicative symbol* background conditions) repeated measurement was carried out to collect reaction time and accuracy data.

Experimental Equipment

1 set of reaction time measuring device (APTECH BD- II-501A).

Experimental Staff

Young people without HUD use experience, aged 23-27, a total of 23 males; with visual acuity or corrected visual acuity of 1.0 or above, without color blindness, and are all right-handed.

Experimental Steps

1) Preparation Before Experiment

Before the experiment, the purpose and process of the experiment were explained and the picture structure instruction was shown to ensure that the subjects understood the meaning of the information presented in the experiment, and the experiment content and the operation. Subjects were required to sign the experiment informed instruction.

2) Preliminary Experiment

The subjects were asked to look at nine pairs of pictures in turn and press the confirm button while speaking the requested information in the center of the screen, the next picture requires the height or speed information reported by the subject. The information appears 4s, and then enters the 2s blank time. During the blank time, a green cross fixation point would appear in the center of the screen to control the visual center of the subjects and ensure their concentration.

3) Formal Experiment

The formal experiment is consistent with the pre-experiment operation process.

4) Data Statistics

By contrast experiment, the cognitive accuracy and response time under different indicators were counted, and the response time and accuracy of three indicators under different background conditions were compared, and the significance and indication of different symbols under different background conditions were analyzed.

CONCLUSION

The IBM SPSS Statistics was used for variance analysis of the experimental results, and the response time and accuracy were processed. The reaction time statistics obtained by the experiment are shown below.

When the digital readings are the same, the response time of each subject to different display interfaces under the same readings is quite different (see Table 3.1). The response time of the subjects to the contents indicated by different indicator symbols has a large gap, but the gap between different readings is small and the fluctuation is relatively average.

Table 3.1 Statistical table of responses of subjects to different digital readings under black background

Digital Reading	Average	Standard deviation	Eta Value
Digital Reading1	1.4094	0.4574	-
Digital Reading2	1.358	0.3688	-
Digital Reading3	1.3385	0.3829	-
Total	1.3712	0.4018	0.073

After using multiple comparisons of the least significant difference (LSD), it is found that there is no significant difference between digital readings 1, 2 and 3 in the response time of subjects, that is, different digital readings have little influence on the response time of subjects.

The response time of the subjects to different symbol styles under the condition of black background is in the order of box arrow > open arrow > closed arrow, indicating a high correlation between symbol styles and response time (see Table 3.2).

Table 3.2 Data statistics of the responses of subjects to different symbol style under the condition of black background.

Symbol style	Average	Standard deviation	Eta Value
Open arrow	1.3545	0.4053	-

Closed arrow	1.5855	0.3883	-
Box arrow	1.1736	0.3025	-
Total	1.398	0.4018	0.422

After using multiple comparisons of LSD, it is found that the open arrow indicator and the framed value indicator resulted in a faster response time，and the average response time of the indicator interface selected by the value box is slightly higher than that of the open arrow.

In conclusion, under the same background conditions, different indicative symbol designs will affect the operational efficiency of pilots.

After excluding the influence of digital readings on the results, three indicators are applied to different background conditions for further study. The result showed that different symbol styles and background conditions have a significant impact on people's cognitive speed.

The sequence of response time of the subjects from fast to slow is box arrow > closed arrow > open arrow (see Table 3.3). The cognitive speed of the three kinds of arrows under the actual background all have different declines, while the open arrow decreases greatly.

Table 3.3 Data statistics of responses of subjects to different symbol styles.

Symbol style	**Mean value**	**Standard deviation**	**Eta value**
Open arrow	1.7897	0.5185	-
Closed arrow	1.5606	0.4061	-
Box arrow	1.4545	0.3739	-
Total	1.6016	0.4550	0.309

After using multiple comparisons of LSD, it is found that the closed arrow and the box arrow has a significant difference in symbol style compared with the open arrow which response speed is faster than the open arrow.

In summary, hypothesis 1 is indeed true, and the guiding efficiency of each symbol is different from that under black background in actual operation. This study shows that the box arrow is a better choice in the HUD interface design of aircraft.

The order of response time from fast to slow is: ground > blue sky > sunset (see Table 3.4).

Table 3.4 Statistical table of response time data of subjects under different background conditions.

Symbol style	Mean value	Standard deviation	Eta value
Daytime sky	1.6324	0.3853	-
Evening sunset	1.8585	0.5108	-
Daytime ground	1.3139	0.2650	-
Total	1.6016	0.4550	0.493

After using multiple comparisons of LSD, it is found that the subjects have the fastest cognition speed of indicative symbols under daytime ground conditions, and cognition speed under evening sunset conditions is the slowest. Hypothesis 2 is true.

The box indicator has the fastest response speed, although the open arrow has a better response speed under the black background, it has the lowest cognitive efficiency under the actual condition (see Figure 3.1).

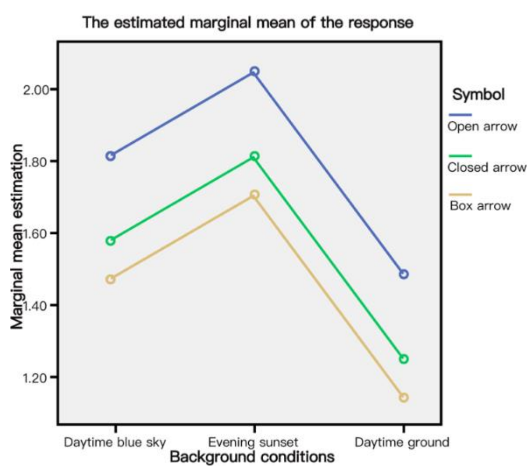

Figure 3.1 Estimated marginal mean of response time

After the experiment, in-depth analysis based on the data. The results showed the overall evaluation of the closed arrow and the open arrow was higher, and the prominence and clarity of the box indicator is higher. The prominence and clarity score of the interface in daytime conditions is low.

In addition, box indicators received higher scores for salience and clarity across all backgrounds. It has better indication and recognition. Moreover, the open arrow has a simpler structure and a smaller proportion of the visual area. Therefore, it has low recognition and readability. This provides theoretical support for the improvement of the fighter HUD display interface from ergonomics and visual information interaction.

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