

Semantic Research of Military Icons Based on Behavioral Experiments and Eye-Tracking Experiments

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Abstract. As a type of symbol, there are four dimensions in icons' symbolic interpretation, namely semantic, syntactic, contextual and pragmatic dimension. Among those dimensions, semantic dimension is the most important one in user's cognitive analysis. Based on the representation of semantics, icons can be classified into four types, namely function-metaphor, operation-metaphor, object-metaphor and meaning-metaphor icon. Here we conducted behavioral experiment and eye-tracking experiment to evaluate those four types of icons selected from military aeronautical system. The behavioral experiment showed that subjects have lowest reaction time to function-metaphor icons and highest accuracy to identify object-metaphor icons. The eye-tracking system showed that subjects have the most fixations when searching for object-metaphor icons and the least fixations when searching for function-metaphor icons. Our research is the first endeavor into the investigation of human's response to different types of icons in the military systems and thus provided novel and valuable guidance to the design of icons in those systems.

Keywords: Aeronautical system · Icons · Semantics · Behavioral experiment · Eye-tracking experiment

1 Introduction

In computer science and software technology, icons are a main part of human computer interfaces, which bridge users and digital interface. As a type of symbol, there are four dimensions in an icon's symbolic interpretation: semantic, syntactic, contextual and pragmatic dimension, among which semantic dimension is the most important one in human's cognitive analysis [1]. Previous psychological study showed that icon's cognition is related to human's cognitive habits, capability of abstract thinking, domain knowledge and cultural background. Generally speaking, icons need be easy to recognize and interpret so that users with no special training can understand the meaning of them. Therefore, the semantic dimension of icons is the most important one. Based on the representation of semantics, icons can be classified into four types, namely function-metaphor, operation-metaphor, object-metaphor and meaning-metaphor icon [1].

A well-designed icon can facilitate the delivery of information and reduce the complexity of a digital interface, thus plays a critical role in digital interface. Based on

the applications, icons can be classified as civil application icons and military application icons, where civil application icons are usually widely used in commercial products and interact with a large population in a daily basis while military application icons are used in military systems, such as geographic information system, operational chain of command system and battle-field situations real-time display system [2]. Comparing to commercial products, military systems have a higher demand in terms of digital interfaces and thus icons, as those systems are critical to assist military persons to accomplish special missions under sophisticated situations. For example, when fighters are carrying out urgent tasks in the air, with the situation changing rapidly, it can easily lead to fighter fleeing. Pilot's decision is directly related to personal life and national security, and that all channels of information acquisition host on the digital interfaces. Therefore icons in those digital interfaces should be designed to enhance pilot's ability to acquire information and reduce pilot's cognitive load in order to assist pilots to make critical decisions and accomplish military tasks. In this paper, we evaluated four types of icons selected from military aeronautical system and based on behavioral experiment and eye-tracking experiment. We provided a framework to compare different types of icons the results provided a novel and valuable guidance to the design of icons in military systems.

The metrics we used to evaluate different icons are accuracy rate, reaction time, fixation point diagram and heat map. Accuracy rate is defined as the ratio of successful operation times to the total operation times. Reaction time is response time, timing from the appearance of stimulus to testers' reacting. Fixation point diagram consists of fixation location switching within the area of interest, which is described by scanning path and used for investigating visual search path and strategy of testers. Heat map reflects the spatial distribution of fixations, with the depth of color indicating the length of time watching this area [3–5].

2 Methodology

2.1 Materials

The experimental materials are icons selected from real military aeronautical systems. As is shown in Fig. 1, icons are selected and redesigned based on expert score and Likert scale. Each row represents one type of icons. Each type of icon is used to represent two words and for each word, we designed two similar but distinct icons. From top to bottom are function-metaphor icons (A), operation-metaphor icon (B), object-metaphor icon (B) and meaning-metaphor icons (D). In the rest of the paper, we will use A, B, C and D to represent those four types of icons separately.

The size of each image is 1024 * 768px, where the size of text is 36pt and the size of icon image is 96 * 96px. And the perspective is controlled in 0.7 degrees, which is equivalent to reading an icon with the size of 0.5 cm * 0.5 cm at a distance of 40 cm [6].

2.2 Subjects

Twenty students, with thirteen males and seven females, whose ages are all between 20–35 years old, 14 males and 6 females, are chosen as subjects. Among those, 15 are with related background knowledge and 5 are without. They all satisfy the following

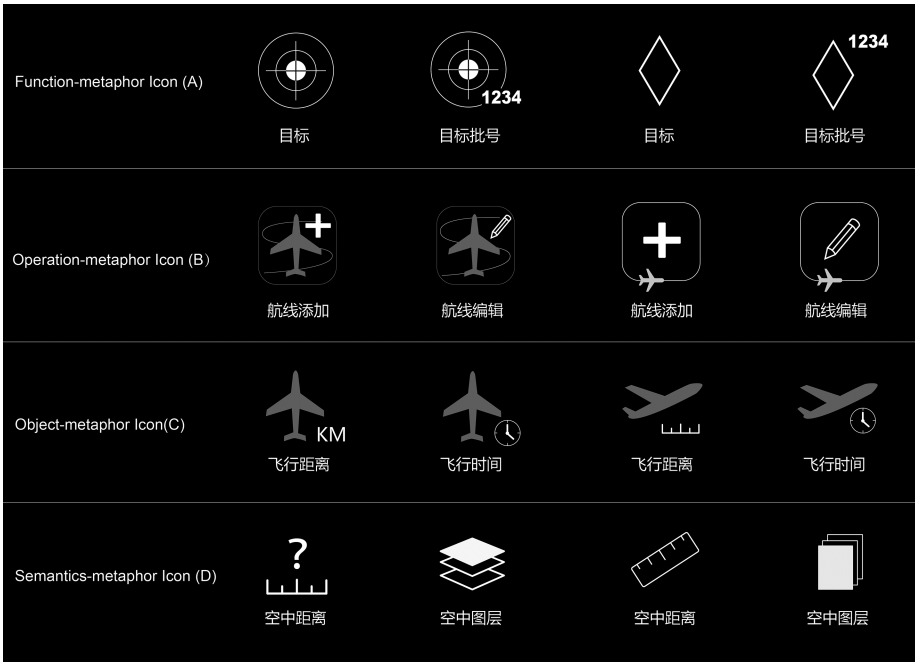


Fig. 1. Icons from military aeronautical systems

conditions: physical and mental health, normal or rectified vision, and with many years’ experience in using graphics device. Subjects are trained to be familiar with task flow and operation requirements before the formal experiment. During the experiment, subjects are asked to keep their eyes 550–600 mm away from the screen and both horizontal and vertical perspective is controlled in 2.3 degrees [7] (Fig. 2).

2.3 Experimental Equipment and Experimental Procedures

Behavioral data includes the accuracy rate and reaction time, which were acquired by Eprime. The eye movement data includes fixation point diagram and heat map, which were

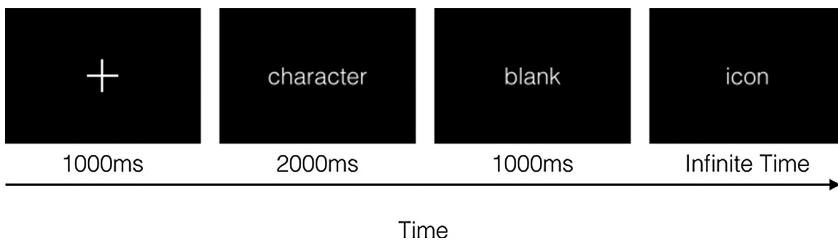


Fig. 2. Process of behavioral experiment

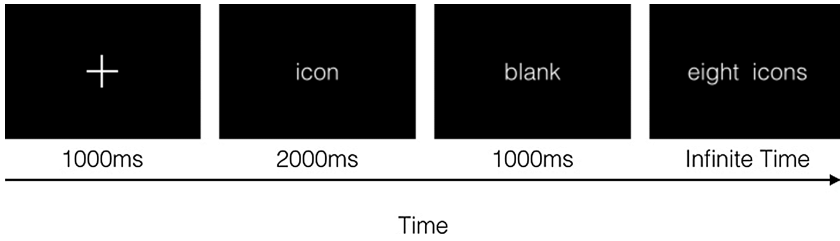


Fig. 3. Process of eye-tracking experiment

acquired by Tobii X2-30 Eye-tracking Device. Behavioral experiment and eye-tracking experiment were conducted separately, and specific information was as follows [8].

Behavioral experimental procedure is as follows. Each experiment covers all icons in A, B, C and D which accounts for 16 trials. In each trial, there are four phases: Phase I: a white cross appeared in the center of the screen with the background to be black, and continuously lasted for 1000 ms then disappeared; Phase II: text appeared in the center of the screen, and continuously lasted for 2000 ms then disappeared. In this phase, subjects are asked to remember and understand the text; Phase III: blank appeared and continuously lasted for 1000 ms then disappeared. This phase is to eliminate visual persistence; Phase IV: an icon picture appeared in the center of the screen and the subject is asked to decide whether the semantics of the icon matches that of the text in Phase II. Then the subject is asked to press key 'A' to indicate a correct match and press key 'L' to indicate an incorrect match. After pressing the key, subject enters the next trial. During the experiment, each icon will show up twice, once with the matched text and once with a mismatched text in random sequence.

Next we used Tobii X2-30 to conduct eye-tracking experiment. The process is as follows: Phase I: a white cross appeared in the center of the screen with the background to be black, and continuously lasted for 1000 ms then disappeared; Phase II: an icon appeared in the center of the screen, and continuously lasted for 2000 ms then disappeared. In this phase, subjects are asked to remember and understand the icon; Phase III: blank appeared and continuously lasted for 1000 ms then disappeared. This phase is to eliminate visual persistence; Phase IV: eight icons appeared in the screen at the same time which consist of 2 icons from A, 2 icons from B, 2 icons from C and 2 icons from D. Subjects are asked to conduct visual search task, which is to find the icon that is the same as the one presented in Phase II. After that the subject is asked to press any key to proceed into next trial. During the experiment, fixation time, the fixation number, scan path and heat map are recorded for data analysis [9]. The experiment process is shown in Fig. 3.

3 Analysis and Results

3.1 Behavioral Data Analysis

Behavioral data includes the accuracy rate and reaction time. As is shown in Fig. 4, the average reaction time over all subjects for 4 different types of icons are: operation-metaphor icon (B) 1446.725 ms > meaning-metaphor icon (D) 1328.406 ms > function-metaphor icon

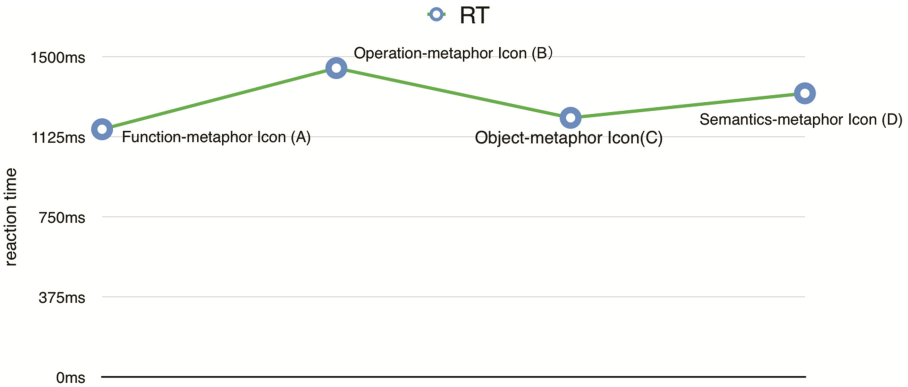


Fig. 4. Reaction time to different icons (behavioral experiment)

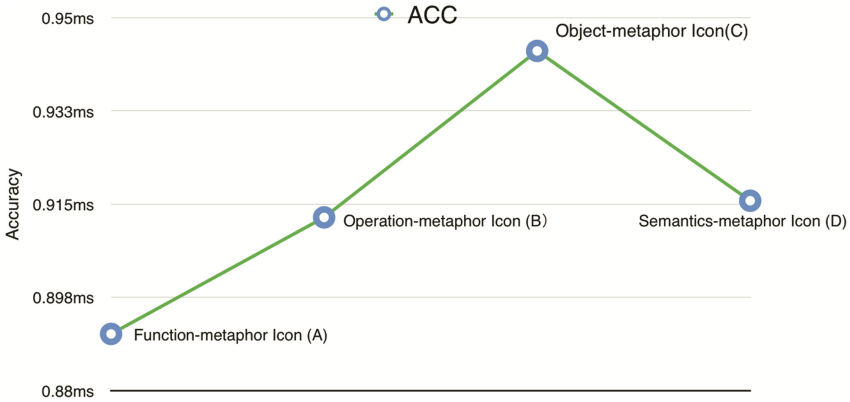


Fig. 5. Accuracy rate of icon recognition (behavioral experiment)

(A) 1213.522 ms > object-metaphor icon (C) 1159.947 ms. The results showed that object-metaphor icons require shortest reaction time while operation-metaphor icons require longest reaction time.

As is shown in Fig. 5, the accuracy rate of identifying icons are: object-metaphor icon (C) 0.944 > meaning-metaphor icon (D) 0.916 > operation-metaphor icon (B) 0.913 > function-metaphor icon (A) 0.891. The results showed that subjects have highest accuracy rate identifying object-metaphor icons.

3.2 Eye-Tracking Experiment Data Analysis

As is shown in Fig. 6, the results of fixation number is as follows: Object-metaphor icon (c) 5.368 > Operation-metaphor icon (B) 5.200 > meaning-metaphor icon (D) 4.950 > function-metaphor icon (A) 4.450. The result suggested that subjects tend to have lower fixation numbers when searching for function-metaphor icons which suggested that function-metaphor icons are easier to be detected by human beings.

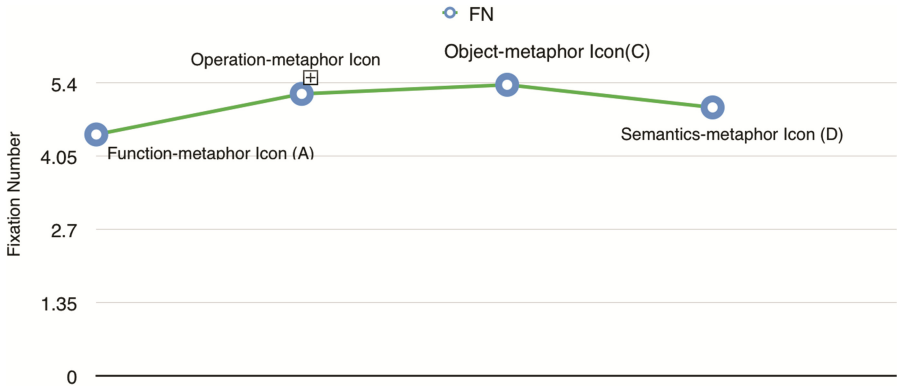


Fig. 6. Fixation Number

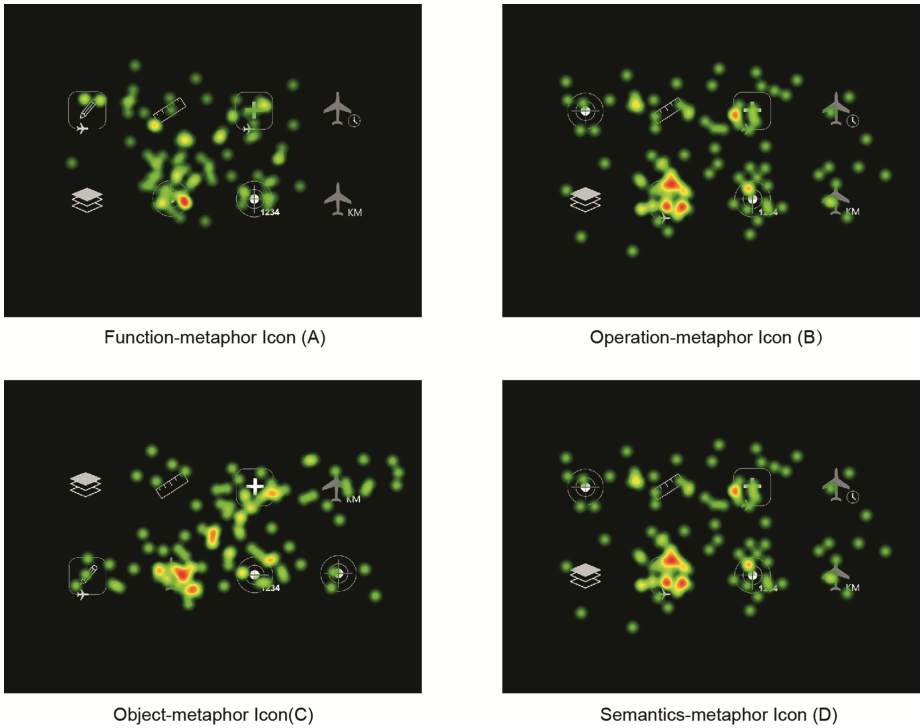


Fig. 7. Heat map

As is shown in Fig. 7, all subjects completed the assigned task, which is to search for icons at the second position of second row. It is also shown in Fig. 7 that heat map of function-metaphor icons are more concentrated comparing to other three types of icons. This suggested that function-metaphor icons easier easy to be identified.

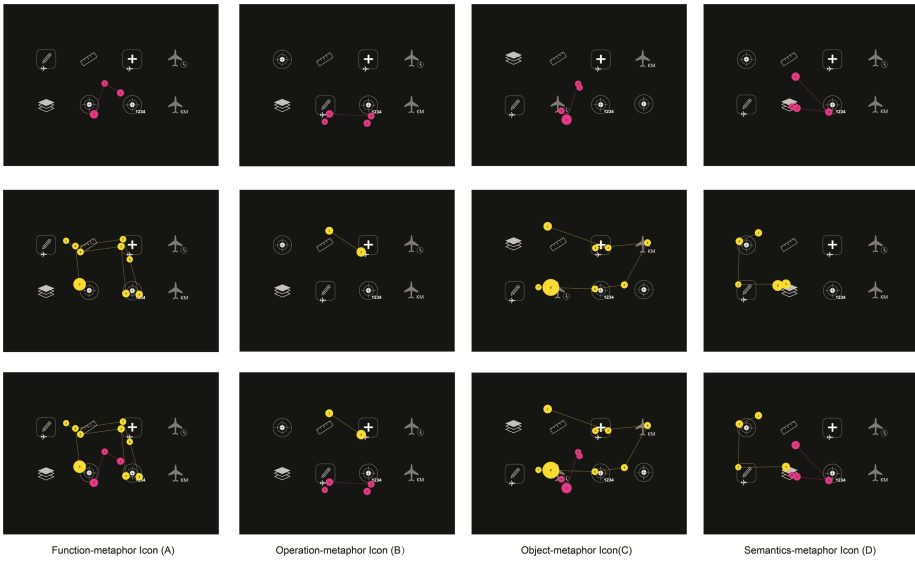


Fig. 8. Fixation point diagram

As is shown in Fig. 8, red dots in the first row represent fixation numbers and scan path of subjects with experience of icon designs while yellow dots represent fixation numbers and scan path of subjects without experience of icon designs. And we combined the results of first row and second row for direct comparison in the third row. The results in Fig. 8 suggested that experienced subjects tend to have small fixation numbers and cleaner scan path with less zigzags.

This conclusion is also consistent with the general practice of icon designs in military systems where function-metaphor icons are preferred. The icons used in this paper also provided a good example of function-metaphor icons in terms of simplicity, recognizability and mnemonically.

4 Conclusions

In this paper, we used Eprime and eye-tracking device to evaluate the icons used in military aeronautical systems. The results showed that function-metaphor icon is better than others in terms of easy to recognize and easy to memorize. Our investigation is the first endeavor into the statistical study of the recognizability and memorability of icons in the military aeronautical systems. The results would provide valuable guidance to further studies and future design of icons in military systems.

Acknowledgement. This paper is supported by National Natural Science Foundation of China (No. 71271053, 71471037), Aeronautical Science Foundation of China (No. 20135169016) and Scientific Innovation Research of College Graduates in Jiangsu Province (No. CXLX13_082).

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