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A Design Method of Icon Based on Semantic Research of Universal Symbols

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Abstract. With the advances in computer technology, graphical interfaces improve substantially software operability and readability. Good icon converts series of complex system commands into an intuitive symbol and enhances software usability by reducing users' cognitive load. In this paper, we study the semantics of universal symbols, the Time to Fixation Mean and Heat Map are carried out by the eye-tracking experiment, then the corresponding icons are designed according to the results of eye-tracking experiment, finally we analyze the efficiency (Reaction time and accuracy) of user's recognition in the e-prime experiment. This paper provides designer with a design method of icons after a quantitative verification.

Keywords. Icon, semantic, universal symbols, E-prime experiment, Eye-tracking experiment

Introduction

With the development of computer technology, software interfaces have undergone tremendous changes in the sense that the graphical user interface (GUI) have improved in operability and readability terms; and one of the most important elements are 'the icon'. Icons are easier to remember than words because they are more concrete [1]. As there are usually large number of icons being used in software, the achievement of a successful, user-friendly and popular GUI relies on icons at a large extent [2]. Icons have become an important interactive media between software and users.

Compared to the asthetic aspect, whether the icon can be recognized quickly and accurately is the primary concern. A good icon is intuitional and figurative as an abstract symbol, which can greatly reduce the memory load and improve the efficiency of visual search behavior [3-4]. Icons with incorrect semantics affect the user's cognition, they can lead to lower efficiency and motivation, and may mislead users too.

Nathalie Cindy Kuicheu pointed out that the semantics of an icon was not the linguistic equivalent associated with the image, but a set of attributes which can be used to describe the given icon [5]. For example: Y. Batu Salman designed a set of icons according to the semantic abstract graph of the emergency medical information system [6]. Sarah Isherwood pointed out that by focusing on interface users' understanding of icons, recent research has shown that it is the closeness of the relationship between icons and functions, known as the semantic distance, that is of prime importance in determining the success of icon usability [7]. Likewise, Fabrizio

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Lambertia pointed out that semantics-based optimization mechanism was used to find the best mapping between icons and functionalities and to expand the set of valid commands [8]. Moreover, Zhou Yuxiao used the Design Semeiology to interpret the four dimensions of the digital interface icon, such as semantics, structure, context and pragmatics [9].

Several theories on the semantics of icons have been proposed. We have also concucted research on the semantics of icons. We empirically evaluated four types of icons semantics (icons in the military system), namely function-metaphor, operation-metaphor, object-metaphor and semantics-metaphor icon [10]. This paper can be seen as a follow-up of our previous work. All in all, we can see that many research focus on semantics of icons, and reveal the importance status of semantics recognition.

In this paper, we studied the semantics of universal symbols and gave a quantitative description on icon semantics. We provided a design method of universal icons to designers, which can be varified in a quantitative and scientific way. Specifically, our method follows three steps. First, symbols are selected based on expert score and Likert scale. Data of response time and eye-gazing duration of different types of symbols were collected by the eye-tracking experiments, symbols are good for icons design are found. Second, we design icons depend on the selected symbols referring to the results of eye-tracking experiments. Third, we assess the efficiency of user's recognition of these design icons. Our design method can be varified by analyzing the reaction time and the accuracy in the e-prime experiments.

1. Experimental factors

1.1. Icon size

In order to exclude the impact of interference factors, the density of interface information needs to be carefully considered. The general size are 16 * 16px, 32 * 32px, 64 * 64px, 128 * 128px, 256 * 256 px. The 256 * 256 px is more common in the windows version of the system. Low operating system version are not supporting large size icons, so the selection of the icon is according to the background size. In order to match the experimental equipment, the device screen size has been set to an unified size 1024 * 768 px, so the size of interface will be set to 1024 * 768 px in order to match the device screen, where the size of text is 36pt and the size of icon image is 64 * 64px. The perspective is controlled in 0.7 degrees, which is equivalent to reading an icon with the size of 0.5cm X 0.5cm at a distance of 40 cm [6].

1.2. Interface layout

The rate of experimental interface content should not exceed 40% overall screen [11] to aviod anxiety and psychological burden, and the rate of screen coverage also can not be too low, because it will lead to the user's attention rate dispersion. In order to maintain the appropriate ratio, graphic symbols were evenly distributed in line pixel grids on the background picture in AI (Adobe Illustrator) [12]. The location and the stimulus elements are exactly the same, three interfaces were designed as 1 * 1, 2 * 1 and 2 * 4, which are applied into two experiments.

1.3. colors affection

Colors will affect the results of experiments, so the color of background is black(HSB color system indicates 0° 0% 0%), the color of icon is white(HSB color system indicates 0° 0% 100%) or gray(HSB color system indicates 0° 0% 60%) and the color of font also is white(HSB color system indicates 0° 0% 100%) in the experiment, these made the experiment without color tendency interfered [13].

2. Methodology

2.1. Experimental equipment and Materials

There are three experimental phases in this study **I**: An eye-tracking experiment (using Tobii X2-30 Eye-tracking Device) where genric symbons are used; **II**: Depending on the eye-tracking results, the corresponding icons were designed (You could re-phrase this, so it could be consisten with the previous point. For esmaploe Icons were designs, depending on the eye-tracking results previosuly obtained; **III**: A behavioral experiment conducted in order to test the designed itcons (unsing E-Prime software).

In the Experimental task **I**, icons are selected based on expert scores and Likert scale. Some of them have semantics similarity, whereas others have different semantic indicators. So that the experimental materials have comparison of similar semantic symbols and also include no correlation semantic symbols [14-15].

2.2. Subjects

Twenty students, whose ages are between 20~35 years old, 14 males and 6 females, are chosen as subjects. Among those, 15 are with related background knowledge whose major are computer sciense and 5 are not familiar with the field. 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 [16].

3. Experimental procedures and Results Analysis

3.1. Experimental task I

3.1.1. Eye-tracking experiment

The experimental process is as follows. Phase I: a white cross appears in the center of the screen and lasts for 1000ms after which it disappears. Phase II: a word appears in the center of the screen and lasts for 2000ms. In this phase, subjects are asked attend and memorize the word. Phase III: a 1000 ms blank screen. Phase IV: eight symbols appear on the screen at the same time. Subjects are asked to conduct a visual search task to find the semantic symbol which can matched with the word presented in Phase II. After that, the subject is asked to press any key to proceed to next trial. The interfaces are shown in Fig. 1.

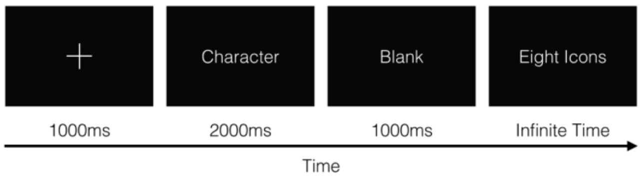

Figure 1. Procedure of eye-tracking experiment.

The Reaction Time and the recognition symbol were explored. Three types of time data were respectively recorded in this experiment. Time for the First Fixation (seconds) referred to as TFF: the average length of time of the first time to enter the interest area. The Duration of the First Fixation (seconds) referred to as FFD: average length of time in the area of interest for the first time. The longer the time, the greater the salience of the region. Fixation Duration (seconds) referred to as FD: the total average length of time in the interest area. The longer the period, the greater the salience of the region. Three standard comparison are used to study the accuracy of the semantic expression of the icon.

3.1.2 Eye-tracking data analysis

Fixation time data analysis

Eight symbolic data curves are more complex and messy, we compare the data of two symbols which have the top-two shortest fixation time.

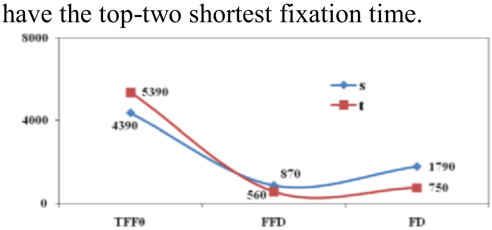

Figure 2. Fixation time of the "time" symbol.

Figure 2 shows the results of the "time" symbol. The blue line represents the symbol "s" and the red line represents the symbol "t" (The time unit is ms). TFFθ of symbol "t" is faster than the symbol "s", but FFD of symbol "s" is slightly faster than the symbol "t", and FD of symbol "s" is faster than "t". The results proves that "s" is more suitable than "t" as a symbol for calculating time function - its universal property is higher than the symbol "t".

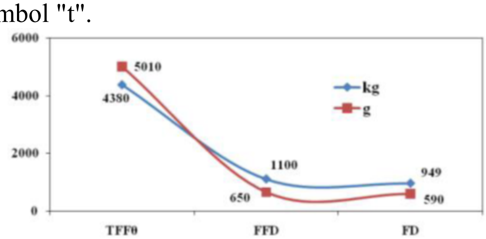

Figure 3. Fixation time of the " weight " symbol.

Figure 3 shows the results of the "weight" symbol. The blue line represents the symbol "kg" and the red line represents the symbol "g" (The time unit is ms). TFFθ of symbol "g" is faster than the symbol "Kg", FFD of symbol "Kg" is slightly faster than the symbol "g", and FD of symbol "Kg" is faster than "g". The results proves that "kg" is more suitable than "g" as a symbol for calculating weight function - its universal property is higher than the symbol "g".

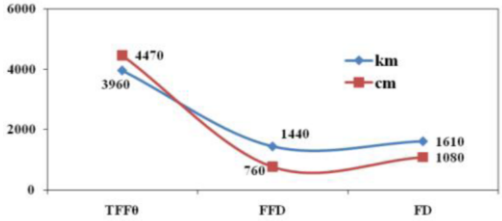

Figure 4. Fixation time of the " distance " symbol.

Figure 4 shows the results of the "distance" symbol. The blue line represents the symbol "km" and the red line represents the symbol " cm " (The time unit is ms). TFFθ of symbol "cm" is faster than the symbol "km", FFD of symbol "km" is slightly faster than the symbol "cm", and FD of symbol "km" is faster than "cm". The results proved that "km" is more suitable than "cm" as a symbol for calculating distance function - its universal property is higher than the symbol "cm".

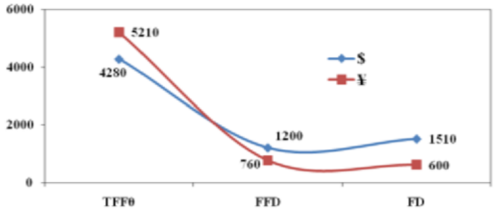

Figure 5. Fixation time of the " money " symbol.

Figure 5 shows the results of the "money" symbol. The blue line represents the symbol "$" and the red line represents the symbol "¥" (The time unit is ms). TFFθ of symbol "¥" is faster than the symbol "$", but FFD of symbol "$" is slightly faster than the symbol "¥", and FD of symbol "$" is faster than "¥". The results proves that "$" is more suitable than "¥" as a symbol for calculating money function - its universal property is higher than the symbol "¥".

Heat Map

Studying the user's attention area and attention distribution through the heat map helps us intuitively find some unqualified experimental data and explore the effectiveness of the task's implementation, which can ensure the accuracy of the experiment.

As shown in Fig. 6, all subjects completed the assigned task. The results indicated that the best universal property symbol of calculating distance function is "km", the best universal property symbol of calculating time function icon is "s", the best universal property symbol of calculating money function is "$", and the best universal property symbol of calculating weight function is "kg".

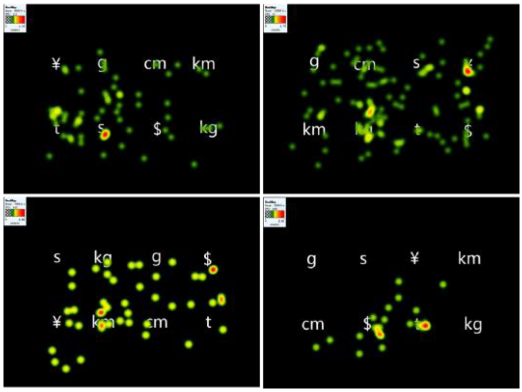

Figure 6. Heat Map.

3.2. Experimental task II

We use AI (Adobe IIlustrator) to design the icons according to the results of eye-tracking experiment. The results of task1 are the elected symbols-"S","Kg", "km", "$", which are the best universal symbols to representative separately "Time","Weight","Distance","Money". These universal symbols are used to design the object-metaphor icon, In order to verify if this method is effectively, we need to compare semantics-metaphor icon with other kinds of metaphor icon. We choose object-metaphor icon, because semantics-metaphor icon is an abstraction image and object-metaphor icon is an object image on the contrary [9-10]. Experimental task II need to design object-metaphor icon and semantics-metaphor icon, which are completed by a designer, icons are shown in Fig 7, the top is semantics-metaphor icon and the bottom is object-metaphor icon. After that the grid line was made horizontal and vertical staggered, and the icons are insert into the desired location in different pages, as is shown in Fig 8, the left icon is semantics-metaphor icon of "Distance", and the right is object-semantics-metaphor icon of "Distance". Many factors have explainted in the “experimental factors” of this paper.

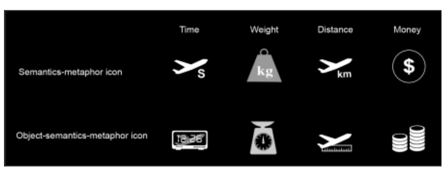

Figure 7. Expermental task II.

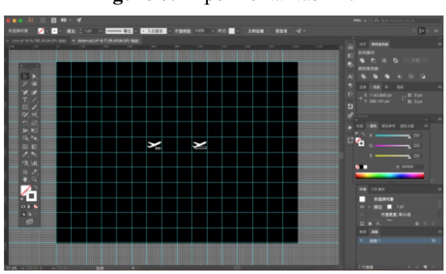

Figure 8. Interface of AI.

3.3. Experimental task III

3.3.1. E-prime experimental

In experiment III, in order to verify the design method scientifically. The icons which are designed in experimental task II are used as the materials, and the user's efficiency (response time and accuracy) of the icon recognition is analyzed by E-prime software. Experimental procedure is as follows: The instructions are displayed on the screen without time limit, the subject reads the instructions carefully, after that the subject is asked to press any key to proceed into the experiment. There are 4 trials in experimental III and each icon “Time”, “Distance”, “Weight”, “Money” will show up in sequence. Each trial covers two icons, one is semantic-metaphor icon and the other is object-metaphor icon. There are four phases in each trial, Phase I: a white cross appears in the center of the screen with the background being black, which lasts for 1000ms then disappears; Phase II: text appears in the center of the screen and lasts for 2000ms then disappeared. In this phase, subjects are asked to remember and understand the text; Phase III: blank appeares and continuously lasted for 1000ms then disappeared. This phase is to eliminate visual persistence; Phase IV: two icons appear in the center of the screen and the subject is asked to decide which one’s semantics match the text in Phase II. Then the subject is asked to press key ‘A’ to choose the left icon and press key ‘K’ to choose the right icon. After that the subject proceeds into the next trial.

3.3.2. E-prime experimental data analysis

E-prime experimental data include the accuracy rate and reaction time.

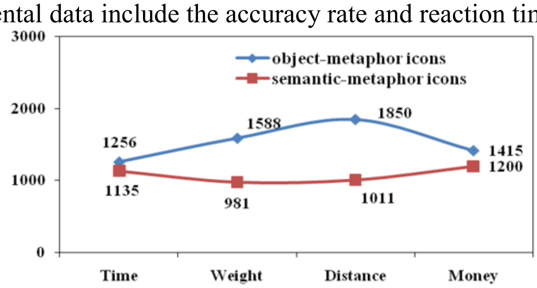

Figure 9. Reaction time to different icons.

Figure 9 shows the reaction time of semantic-metaphor icons and object-metaphor icons, it can be concluded that the time of the subjects identifying the object-metaphor icons are longer than the semantic-metaphor icons.

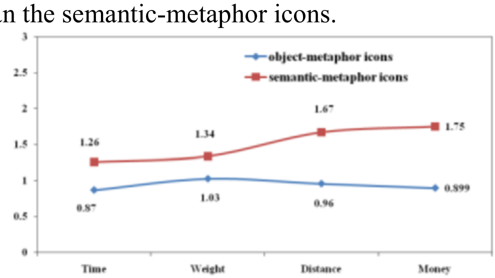

Figure 10. Accuracy rate of icon recognition.

Figure 10 shows the accuracy rate of recognizing semantic-metaphor icons and object-metaphor icons. It can be concluded that the accuracy rate of the semantic-metaphor icon is higher than the object-metaphor icon.

4. Conclusions

This paper studies the universal property of symbols. The corresponding icons are designed according to the results of eye-tracking experiments, in addition to we explored which kind of icon is identified faster and more accurate between the semantic-metaphor icon and object-metaphor icon. The quantitative analysis of the semantics of symbols and icons are carried out, the semantic-metaphor icons with the higher universal property, obtain higher cognitive accuracy and lower cognitive load than the object-metaphor icon. We find that the universal symbol is well used to design an icon, this is an useful design method for the semantic-metaphor icon.

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