Visual and Cognitive Features on Icon Effectiveness

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Abstract—Several criteria like conspicuity, legibility, distinctiveness, and comprehension must be met for an icon to be effective. Previous studies found that visual and cognitive features of icons have significant influence on reaching the criteria for icon effectiveness. The aim of this paper is to present a review on visual features (color, shape, size) and cognitive features (familiarity, concreteness, complexity, meaningfulness, semantic distance) of icons. The relationships amongst cognitive features and ways to quantify cognitive features were also identified. Such review would be helpful in formulating research plans and methodology for conducting other icon studies. In addition, this review would facilitate graphic designers to create more user-friendly icons.

Index Terms—icon effectiveness, visual features, cognitive features

I. INTRODUCTION

The terms like icons, signs, symbols, pictograms, pictographs, and glyphs often appear and appear to be interchangeable in literature. All of them are used to depict physical objects, concepts, or functions. In general, an icon contains an image of some recognizable objects. The image usually appears with a border around it and a background surface. Fig. 1 shows standard parts of an icon. There are several criteria for an icon to be effective. Examples are conspicuity, legibility, distinctiveness, comprehension, reaction time, and behaviour [1].

Visual features like color, shape and size of icons were found to have influence on reaching the criteria for icon effectiveness. Wang *et al.* [2] found that pictorial-color was a significant factor for subjects' visual identification performance on hazardous labels with red, green or blue background. Subjects' visual identification performance was better when the pictorial-color was black than white. Shieh and Huang [3] revealed that pictorial size and circle-slash thickness influenced glance legibility for prohibitive symbols under degraded situations. Duarte *et al.* [4] indicated that pictorial symbol, color and shape are extremely important factors affecting people to understand a symbol.

In addition to visual features, cognitive features of icon familiarity, concreteness, complexity, meaningfulness, and semantic distance [5] were also found to have effects on attaining the criteria for icon effectiveness. McDougall *et al.*

[6] found that icon complexity had significant effect on visual search performance. Ben-Bassat and Shinar [7] revealed that sign comprehension positively correlated with sign familiarity and sign-content compatibility. Ng and Chan [8] studied the variation of influence of cognitive features on traffic sign comprehension. In situations where signs are not learned before, semantic distance is required as primary consideration in sign comprehension, followed by familiarity, meaningfulness, concreteness, and complexity. For recently learned signs, the effects of semantic distance and meaningfulness on sign comprehension were found to last longer than those of familiarity, concreteness, and complexity.

In this paper, a review on visual and cognitive features of icons was presented. Three visual features of color, shape and size, and five cognitive features of familiarity, concreteness, complexity, meaningfulness, and semantic distance were examined. The relationships amongst cognitive features and ways to quantify cognitive features were also identified. Such review would be helpful in formulating research plans and methodology for conducting icon studies in the future. In addition, it would provide designers a clearer picture on both visual and cognitive features of icons and thus facilitate them to create more assessable and effective icons.
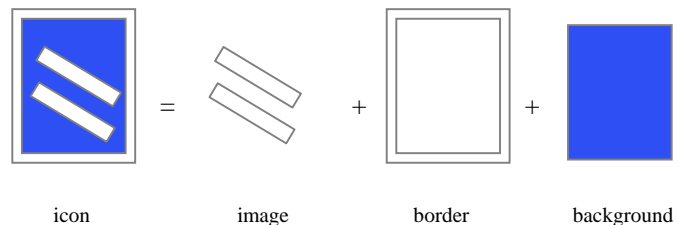

icon   image   border   background

Fig. 1 Standard parts of an icon which represents 200 meter to an exit along the roads and highways in Hong Kong.

II. VISUAL FEATURES

A. Color

Colors not only direct attention to icons but also convey the level of hazard [9]. For a group of Spanish speaking people, Wogalter *et al.* [10] found that red connoted the greater hazard than orange, black, yellow, green, magenta, blue, brown, gray, and white. For Chinese subjects, Luximon *et al.* [11] showed that red had the highest perceived hazard level, followed by yellow and orange, and then blue, green and white. In a study of color associations [12], Hong Kong Chinese subjects were asked to associate 16 concepts with 10 colors. The strongest color-concept associations, which coincided with daily experience of the subjects, were red and stop (66.4%), red and danger (63.0%), and green and go (62.6%). The above findings indicated that graphic designers should use appropriate color codes to express different intensities of

hazard in icon design, and red is prescribed to deliver the greatest hazard warnings.

B. Surround shape

Similar to color, surround shapes can be used to transmit conventional meanings and levels of hazard. For example, circular and triangular traffic signs in Hong Kong give orders and warning, respectively [13]. Yu *et al.* [14] studied the perception of hazard of surround shapes of the Chinese population. They found that upright triangle connoted the greatest hazard, followed by inverted triangle, diamond, circle, and rectangle. Kurniawan [15] indicated that icons performing similar functions should bear family resemblance to increase family distinctiveness. As colors and shapes help to create conceptually related meanings, icon families can be created by using colors and shapes to highlight similarities between icons which represent similar type of information. For instance, a safety sign with a red circle-slash means that something must not be done in the Chinese National Standard [16].

C. Red Circle-Slash

A red circle with a slash overlaid on a pictorial is often used to depict a negation. Previous studies examined various kinds of red circle-slash for prohibitive symbols. Dewar [17] investigated the glance legibility of prohibitive symbols with four types of circle-slash: slash over symbol, slash under symbol, partial slash, and no slash. The results indicated that the glance legibility for no slash and partial slash were better than that for over and under slashes to convey prohibitive message. Murray *et al.* [18] investigated the acceptability of prohibitive symbols under each of four conditions - slash over symbol, slash under symbol, partial slash, and translucent slash. The results showed that the over and under slashes were preferred to the translucent or partial slashes, but the over slashes were given lower evaluations when critical symbol elements were obscured.

The components of prohibitive symbols such as pictorial solidity, pictorial size, and orientation and thickness of red circle-slash were significant factors affecting preference ratings of the prohibitive symbols [19]. Solid pictorials rated more preferable than pictorials in outline form. Pictorials size equal to or greater than 75% of the inner diameter of a circle-slash were rated better than pictorials 50% in size. Diagonal slashes were rated higher than vertical or horizontal ones. Circle-slash thickness was rated better when its resulting area comprised at least 25% of the total area inside its outer circle.

Pictorial size and red circle-slash thickness not only influenced the preference ratings but also glance legibility for prohibitive symbols [3]. It was found that glance legibility for the 50% pictorial size (i.e. length of the pictorial/diameter of inner circle of prohibitive symbol) was significantly lower than that for the 75% and 100% sizes. Regarding the circle-slash thickness (i.e. area of the circle-slash/total area inside the outer circle of the prohibitive symbol), glance legibility for the 45% thickness was significantly lower than that for the 25% and 35% thickness.

D. Icon size

When an icon is set at the minimum size, its key features must be discriminable and identifiable easily [20]. In a display, the precise size of an icon is usually determined by viewing distance, display quality, and viewing condition [9]. Display quality may depend upon resolution, contrast, focus, and glare. Viewing condition differs in accordance with environmental (e.g. noise, smoke, and dust), physiological (e.g. fatigue, eye strain), and psychological factors (e.g. workload, stress, and anxiety).

III. COGNITIVE FEATURES

A. Familiarity, concreteness, complexity, meaningfulness, and semantic distance

Five cognitive features are of central concern in icon research [5]. They are familiarity, concreteness, complexity, meaningfulness, and semantic distance. Familiarity is defined in terms of the frequency with which icons had been encountered. Icons are regarded as concrete if they depict real objects, materials, or people; those that do not are considered as abstract. Icons are regarded as complex if they contain a lot of details or are intricate, and they are simple if they only contain few elements or little detail. Meaningfulness refers to how meaningful the judges perceive icons to be. Semantic distance is a measure of the closeness of the relationship between what is depicted in an icon and the function it is intended to represent. To build more consistent order of response scales amongst the five cognitive features of icons, the terms 'complexity' and 'semantic distance' were revised as 'simplicity' and 'semantic closeness', respectively in a study on traffic signs [21].

B. Relationships amongst cognitive features

The existence of interrelations between cognitive features was found [5, 21]. Without consideration of subject experience with icons [5], icon familiarity, concreteness, meaningfulness and semantic distance were strongly interrelated, whereas icon complexity did not correlate closely with other features. Previous research found that subject experience would affect the perception on icon semantic distance [22]. For a group of novice subjects [21], significant and positive relationships were found amongst the cognitive features of familiarity, concreteness, meaningfulness, and semantic closeness. Other than with familiarity, simplicity did not correlate with the other four features. Another study is needed for generalization of the results for experienced subjects. The findings here indicated that the amount of variability on the perception of one cognitive icon feature would be affected by others.

C. Ways to quantify cognitive features

When no measures of cognitive features (e.g. concreteness) were available, researchers had to rely on their own intuitions in order to decide whether an icon was concrete or not [23, 24, 25]. There are three empirical methods for quantifying cognitive features, viz. subjective rating [5], metric [26], and

automated measurement [27], which are critical in analyzing the relationship between cognitive icon characteristics and user performance.

i) Subjective rating

McDougall *et al.* [5] devised subjective rating method to measure the five cognitive features (i.e. familiarity, concreteness, complexity, meaningfulness, and semantic distance). For each feature, subjects use bipolar adjectives on a five-point scale to indicate their perceptions on an icon. Instead of using the five-point scale, Ng and Chan [21] employed a 0 to 100 points scale for rating cognitive features as it was believed that respondents prefer to express their feelings on a 0 to 100 scale [28] and a higher number of scale points usually results in greater spread of data and makes the data more amenable to various kinds of statistical analyses [29]. For each sign, subjects were asked to give subjective ratings for familiarity (0 = very unfamiliar, 100 = very familiar), concreteness (0 = definitely abstract, 100 = definitely concrete), simplicity (0 = very complex, 100 = very simple), meaningfulness (0 = completely meaningless, 100 = completely meaningful), and semantic closeness (0 = very weakly related, 100 = very strongly related).

ii) Metric

García *et al.* [26] proposed metric for measuring an icon feature, concreteness. The metric value of a particular icon is obtained by adding up the number of the following components in the icon: closed figures, letters, open figures (i.e. where the figure's outline is not continuous), special characters (e.g. ?, =), horizontal lines, vertical lines, diagonal lines, arrowheads, and arcs. Fig. 1 illustrates a sample icon that has a metric value of four. This value is determined by adding up four closed figures. The basis of the metric is: icons that are more complex are perceived as being more concrete – the larger the metric value, the higher the level of concreteness. However, McDougall *et al.* [5] revealed that the association between icon concreteness and complexity was not statistically significant, and showed that the metric had similar measurement of icon complexity instead of concreteness.

iii) Automated measurement

Forsythe *et al.* [27] developed a fully automated measurement on icon complexity by using three image processing functions in Matlab software, viz. perimeter determination, Canny edge-detection, and quadtree decomposition. As compared with the subjective rating method on complexity and metric, the three image processing functions were capable of producing reliable estimates of perceived icon complexity.

Up to now, it is evident that subjective rating is the most comprehensive approach to quantify the five cognitive features, while metric and automated measurement can only be used to measure icon complexity.

IV. CONCLUSION

A review on visual and cognitive features of icons was presented in this paper. Three visual features of color, surround shape and icon size, and five cognitive features of familiarity, concreteness, complexity, meaningfulness and semantic distance were identified and discussed. However, the relative importance of such features has never been determined. Further research is needed to assign relative weights to the features so that icons can be designed in a more accessible and effective way. The relationships amongst cognitive features and ways to quantify cognitive features were also summarized. This review would provide graphic designers a clearer picture on both visual and cognitive features of icons, and would be helpful in formulating research plans and methodology for conducting other icon studies.

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