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# Integrating Conjoint Analysis with TOPSIS Algorithm to the Visual Effect of Icon Design Based on Multiple Users' Image Perceptions

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**ABSTRACT**
With the advance of mobile computing and wireless technology, a user's intent to interact with the interface of a mobile device is motivated not only by its intuitional operation, but also by the emotional perception induced by its aesthetic appeal. A graphical interface employing icons with suitable visual effect based on the users' emotional perception plays an essential role in determining the possibility of users' interaction with an interface of mobile device. This study commences to develop an integrated design approach based on Conjoint Analysis and TOPSIS Algorithm to the visual effect of icon design. The "Facetime App" icon is chosen for illustration purposes. A series of evaluation trials are then performed to establish the correlation between the icon visual effects and the users' image perceptions of the icon. The integrated design approach can assist designers obtain effective information to develop the icon candidates of various visual effects so as to match the demands of multiple users' image perceptions. Although this study takes just the "Facetime App" icon as an example for illustration purposes, the integrated design approach is equally applicable to various types of icons shown on the interface of mobile device.
**Keywords:** icon design, visual effect, conjoint analysis, TOPSIS, image perception

## INTRODUCTION

As technology in wireless and mobile computing advances, the market for handheld devices such as cell phones and tablet computer is rapidly growing. User-centered perception design plays an essential role in determining the possibility of users' interaction with an interface of mobile device. One of the fundamental aims of any user-centered interface design is to not only facilitate efficient performance, but also enhance positive emotional response, e.g., pleasurable feeling, aesthetic evaluation, psychological image perception and so on. Recent researches have shown that enhancing the aesthetic appeal of an interface is as important as


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**State of the literature**

- This study has constructed the four basic relationships between icon visual effects and users' image perceptions for aiding the designer to comprehend the likely user reaction.
- The icon design activities are commonly relied on the designers' opinions. This study has scientifically developed an integrated design approach in order to avoid the personal subjectivities in the design process.
- The icon visual effect design based on single image perception cannot generate suitable alternatives while considering multiple image perceptions simultaneously. The integrated approach based on Conjoint Analysis and TOPSIS algorithm has conducted to illustrate its feasibility for matching the multiple image perceptions.

**Contribution of this paper to the literature**

- This study has demonstrated the ability of the integrated design approach to not only match the multiple users' image perception requirements, but also generate an optimized icon visual effect for enhancing the pleasurable feeling or aesthetic evaluation when interacting with an interface.
- The conspicuous difference between the integrated design approach and the traditional KE approaches has been pointed out and discussed in the current study.
- The result of this study provides useful insights for designing the icon visual effect which more closely matches the users' image perception expectations.

improving its usability, and aesthetically pleasing designs tend to increase users' positive responses to the usability of an interface (Tractinsky, 2004; Hassenzahl and Tractinsky, 2006; Reppa et al., 2008; McDougall and Reppa, 2008). A graphical user interface, employing icons, provides an easy and friendly interaction way with applications, and can reduce the mental workload of users when the icons are designed properly (Goonetilleke et al., 2001; Schröder and Ziefle, 2006). A high quality of aesthetic icon, such as form style, visual effect, color, and so on, is advantageous in catching users' eyes (Huang et al., 2002; Reppa et al., 2008; McDougall and Reppa, 2008). The visual effect of icon shown on the iconic interface has become more important since a satisfactory icon can evoke their pleasurable feeling or image perception, increase users' interest, and promote the users to interact with the specific applications. However, the icon design activities are commonly relied on the designers' opinions and personal subjectivities, with no theoretical basis. To avoid, or at least alleviate, the need for subjective judgments in the design process and to objectively relate users' psychological satisfaction with an icon to its visual effects, the concept of Kansei Engineering (KE) (Nagamachi, 2002; Huang et al., 2012) is introduced in this study. KE is as an ergonomic approach for developing product image design to satisfy users' psychological image perceptions. It has been applied successfully in the design field, such as product form design (Chang and Chen, 2014), icon design (Tung et al., 2009), web page design (Lin et al., 2013), and suit fabric texture design (Chuang and Hung, 2011) and so on.

In general, the effectiveness of the product image design approach is crucially determined by the choice of analytical techniques used to model the correlation between the product attribute and the corresponding users' image perception (UIP). Techniques such as Conjoint Analysis (CA), Taguchi method, Multiple Regression Analysis (MRA) and Quantitative Theory Type I (QTT1) are commonly employed. In this study, the "Facetime App" icon used in cell phone or tablet computer is chosen for illustration purposes since it has comprehensive recognition and legibility, and hence the users' image perception is governed primarily by its appearance or visual effect. CA is used as an analysis technique for modeling the correlation between the icon visual effects and the UIPs because it is easy, simple, and has high practicability in the result analysis of evaluation trials. However, CA is best suited to dealing with single UIP rather than the multiple UIPs. Icon visual effect design based on single UIP cannot generate practicable alternatives while considering multiple UIPs simultaneously. Accordingly, this study introduces the TOPSIS algorithm (Yoon and Hwang, 1995) to strengthen the capability of the CA to generate icon designs which satisfy multiple UIP requirements. The TOPSIS algorithm is a multi-objective evaluation approach which assesses the overall performance of a design proposal by means of a satisfiability index (SI) which takes simultaneous account of all of the design objectives. The current study combines the advantages of the CA and the TOPSIS algorithm to satisfy the multiple UIPs of icon design. The effectiveness of the integrated design approach is demonstrated through its application to the visual effect of static icon.

The remainder of this study is organized as follows: Section 2 presents the methods and procedures of this study. Section 3 describes the integrated design approach based on CA and TOPSIS Algorithm. Section 4 validates the effectiveness of the integrated design approach. Section 5 presents the discussion and conclusion.

## METHODS AND PROCEDURES

### Visual Effects of Static Icon

This study commences by collecting a large number of cell phone or tablet icons, and approximately 100 static icons are collected. Five experts in the field of interface/graphic design are invited to review these static icons and to establish the icon visual effects most likely to influence the UIP. The icon visual effects are specified as the various design variables of the static icon. **Table 1** presents the 4 attributes which are finally determined, and their corresponding attribute levels. The attributes and the corresponding levels are determined in accordance with the following principles:

- All chosen attributes and levels must be commonly seen in the interface design, and the recognition and legibility of icon will be unaffected.
- The relationship between any two attributes must be independent such that the variation of any single design variable has no influence upon the variation of the other design variables.

**Table 1.** Definition of Icon Visual Effects

| Attributes | Levels | | |
|---|---|---|---|
| | 1 | 2 | 3 |
| Shadow effect *($X_1$)* | None ($X_{11}$) | Plane-shadow ($X_{12}$) | Gradual-shadow ($X_{13}$) |
| Perspective effect ($X_2$) | None ($X_{21}$) | Rightward perspective ($X_{22}$) | Leftward perspective ($X_{23}$) |
| Stereo-effect ($X_3$) | None ($X_{31}$) | Sharp-edge ($X_{32}$) | Round-edge ($X_{33}$) |
| Frame effect with reverse type fill-color (*X4*) | None ($X_{41}$) | Square-frame ($X_{42}$) | Circular-frame ($X_{43}$) |

## Orthogonal Array of Icon Evaluation Samples

To accommodate the 4 attributes and their corresponding levels, an experimental design known as an orthogonal fractional factorial design (orthogonal array or orthogonal design for short) is conducted in this study. The orthogonal array shown in **Table 2** is applied to design the conditions of icon evaluation samples. Finally, the 9 static icon samples shown in **Figure 1** are created in accord with the conditions of orthogonal array table.

**Table 2.** Orthogonal Array of Icon Evaluation Samples

| No. | $X_1$ | $X_2$ | $X_3$ | $X_4$ | Vigorous | Sprightly | Formal | Elegant |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 1 | 1 | 2.95 | 3.93 | 4.01 | 3.70 |
| 2 | 3 | 2 | 3 | 1 | 4.93 | 4.21 | 3.60 | 3.94 |
| 3 | 3 | 3 | 1 | 2 | 3.29 | 4.35 | 2.12 | 3.64 |
| 4 | 2 | 1 | 3 | 2 | 5.45 | 2.17 | 5.86 | 2.83 |
| 5 | 2 | 3 | 2 | 1 | 4.55 | 4.29 | 4.45 | 2.69 |
| 6 | 2 | 2 | 1 | 3 | 2.57 | 4.68 | 2.02 | 4.13 |
| 7 | 1 | 3 | 3 | 3 | 3.69 | 4.85 | 3.50 | 4.42 |
| 8 | 3 | 1 | 2 | 3 | 3.67 | 3.83 | 5.58 | 4.74 |
| 9 | 1 | 2 | 2 | 2 | 4.79 | 2.79 | 3.71 | 3.07 |

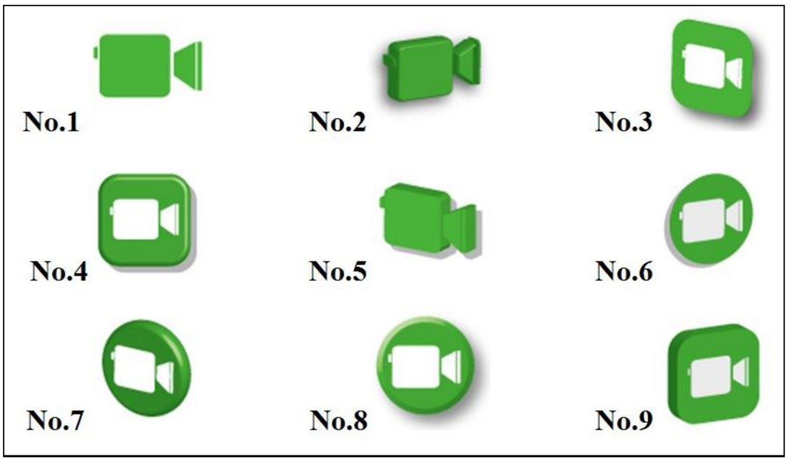



**Figure 1.** Evaluation Samples of static icon

### Selection of Representative UIP Descriptors Regarding the Visual Effect of Static Icon

Although users apply many different image words (descriptors) to express their image response to the specific something, the descriptors applicable to a static icon's image are more limited. In this study, the users' image perceptions (UIPs) toward the visual effect of static icon are described using the 26 descriptors. The descriptors are used as the initial image dimensions for a 7-point Likert scale investigation, in which 22 users (12 male, 10 female and age from 21 to 32 years old) are asked to evaluate a small number of static icon samples. The descriptor evaluation data are then analyzed using the exploratory factor analysis. It is found that the extracted factors accounted for 39.69%, 23.97%, 16.64% and 6.31% of the explained variance, respectively. As shown in **Table 3**, these descriptors are distributed across 4 distinct factors, referred to as representative UIP descriptors. To reflect the common theme of the descriptors within each factor, the 4 representative UIP descriptors are annotated as "Formal", "elegant", "sprightly" and "vigorous", respectively, and they are then used in the subsequent static icon evaluation trial.

**Table 3.** Selection of Representative UIP Descriptors

| Representative Descriptor | Eigenvalue | Explained Variance | Initial Image Dimensions |
|---|---|---|---|
| Formal | 9.42 | 39.69% | formal, harmonious, neat, balanced, complete, symmetrical, quiet, order, proportional, emphatic |
| Elegant | 6.59 | 23.97% | elegant, gradual, smooth, good-looking, classical, soft, tactful |
| Sprightly | 4.09 | 16.64% | sprightly, lively, cadence, simple, fairy, nimble |
| Vigorous | 1.49 | 6.31% | vigorous, strong, free |

## Evaluation trials for the Visual Effect of Static Icon

42 subjects (age from 21 to 32 years old) are invited to evaluate the image perceptions induced by the static icons. The image perceptions are quantified using four 7-point Likert scales, i.e. one scale for each of the four representative UIP descriptors. The 9 static icon samples and the four Likert scales are integrated into an evaluative interface constructed using Visual Basic software, as shown in **Figure 2**. After each subject had evaluated all of the samples, the evaluative data are recorded for statistical analysis purposes. For each static icon sample in **Table 2**, the columns 2-5 show the number coding of corresponding level for each of its four attributes. The last four columns of **Table 2** show the 4 descriptors averages of 9 static icon samples. **Table 2** provides a numerical data source for the CA and TOPSIS, which can be used to develop an integrated design approach for the visual effect of static icon.

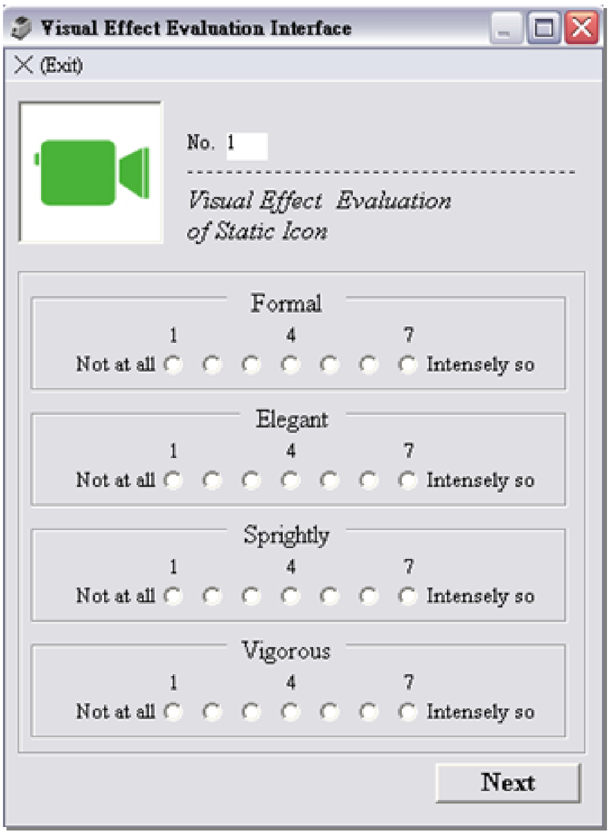



**Figure 2.** Icon evaluation interface

## Construction of the Relationship between Static icon and UIPs

In this study, the UIP evaluation results obtained for the visual effect of static icon are analyzed using Conjoint Analysis (CA) technique. In analyzing the data, the independent variables correspond to the individual design variables in the definition of icon visual effects (see **Table 1**), while the dependent variables correspond to the four representative descriptors used to evaluate the UIPs. Furthermore, since this study treats the task of satisfying UIP for the visual effect of static icon as a multi-objective design activity, the TOPSIS algorithm is introduced to strengthen the capability of the CA technique to generate icon designs which satisfy multiple UIP requirements. Subsequently, an integrated design approach is developed which integrates the CA technique with the TOPSIS algorithm to provide a multiple UIPs design tool which satisfies the users' requirements.

# INTEGRATED DESIGN APPROACH BASED ON CONJOINT ANALYSIS AND TOPSIS ALGORITHM

## Constructing the CA Relationship Models

Based on the orthogonal array shown in **Table 2** and the evaluation results of the four representative descriptors used to evaluate the UIPs for the visual effect of static icon, the CA-based UIP model can be constructed as the following function for the visual effect of static icon in the current study:

$$y_j=\beta_0+\beta_1 x_{1j}+\beta_2 x_{2j}+\beta_3 x_{3j}+\beta_4 x_{4j}+e_j, \quad (1)$$

where $y_j$ represents the evaluation of static icon $j$=1,..., $m$ (a set of m=9 static icon samples) observed from a specific person $i$=1,…, $n$ (a set of $n$=42); $\beta_0$ is a constant term; $\beta_1,\ldots,\beta_4$ are the model parameters indicating the influence of attribute level variation on the static icon sample evaluation to be estimated. The indicator variables $x_{1,j},\ldots,x_{4,j}$ represent a set of dummy variables reflecting the effect-coding for the attribute level combination of sample $j$ ($x_1$: shadow effect, $x_2$: perspective effect, $x_3$: stereo-effect, $x_4$: frame effect). Finally, $e_j$ is an exogenous stochastic nuisance term.

In the current study, **Table 4** indicates the four model relationships between the visual effect of static icon and the corresponding UIP Descriptors, and shows that the Adjusted R2 values vary from 0.953(Vigorous) to 0.984(Elegant). The overall fits of the CA models are good. Furthermore, the four CA functional models in each of the four UIP descriptors can be constructed directly using the data presented in the "Utility" columns of **Table 4**. These CA models provide icon designers with the means to derive the predictive value of likely single UIP to the visual effects of static icon in terms of four UIP descriptors if only offer the number coding of corresponding attribute level for each of its four attributes.

## Integrating CA with TOPSIS Algorithm

As in the case of the CA models described in the "Utility" column of each UIP descriptor of **Table 4**, the four CA models can be integrated with the TOPSIS algorithm so as to develop the optimal icon design alternative for meeting multiple UIPs to icon visual effect image. If a set of specific multi-UIPs to icon visual effect are designated by user groups or icon designers. For example, if a particular user group prefers a new static icon with "intensely Vigorous" (6), "a little bit Sprightly (2)", "somewhat Formal" (3), and "quite a bit Elegant" (5). The integrated design approach proposed in this study can be performed as described in the following eight steps.

**Table 4.** Results of Conjoint Analysis

| | | Vigorous | | Sprightly | | Formal | | Elegant | |
|---|---|---|---|---|---|---|---|---|---|
| | | Im. | Utility | Im. | Utility | Im. | Utility | Im. | Utility |
| $X_1$ | $X_{11}$ | 0.224 | −0.188 | 0.204 | −0.144 | 0.232 | −0.545 | 0.295 | 0.011 |
| | $X_{12}$ | | 0.225 | | 0.043 | | 0.527 | | −0.456 |
| | $X_{13}$ | | −0.037 | | 0.100 | | 0.019 | | 0.444 |
| $X_2$ | $X_{21}$ | 0.236 | 0.058 | 0.332 | −0.599 | 0.359 | 1.304 | 0.214 | −0.064 |
| | $X_{22}$ | | −0.235 | | 0.230 | | −0.609 | | −0.006 |
| | $X_{23}$ | | 0.177 | | 0.369 | | −0.696 | | 0.069 |
| $X_3$ | $X_{31}$ | 0.268 | −0.728 | 0.205 | −0.144 | 0.212 | −0.569 | 0.222 | −0.031 |
| | $X_{32}$ | | 0.336 | | 0.068 | | 0.503 | | −0.122 |
| | $X_{33}$ | | 0.392 | | 0.076 | | 0.066 | | 0.153 |
| $X_4$ | $X_{41}$ | 0.272 | 0.146 | 0.259 | −0.087 | 0.197 | 0.400 | 0.269 | −0.256 |
| | $X_{42}$ | | 0.209 | | −0.274 | | −0.355 | | −0.247 |
| | $X_{43}$ | | −0.355 | | 0.360 | | −0.045 | | 0.503 |
| Constant | | 3.664 | | 3.900 | | 3.720 | | 3.389 | |
| Adjusted $R^2$ | | 0.953 | | 0.972 | | 0.961 | | 0.984 | |

"Im." indicates that the importance of visual effect attribute for static icon

Step 1: the TOPSIS decision matrix D, i.e. the Vigorous, Sprightly, Formal, and Elegant predictive values of 9 static icon samples generated by four CA models, is calculated as

$$D = \begin{bmatrix} S_{11} & S_{ij} & \cdots & S_{1n} \\ S_{21} & S_{22} & & S_{2n} \\ \vdots & \vdots & & \vdots \\ S_{m1} & S_{m1} & \cdots & S_{mn} \end{bmatrix} \quad (2)$$

where Sij is the predictive value of the *i-th* sample for the *j-th* UIP.

Step 2: these predictive values are then normalized across all of the UIPs, and the normalized value of each sample for UIP, $r_{ij}$, is calculated, i.e.

$$r_{ij} = S_{ij} \Big/ \sqrt{\sum_{i=1}^{m} S_{ij}^2}\ , \ i = 1,\ldots,9, \ j = 1,\ldots,4 \quad (3)$$

Step 3: calculate the weighted normalized decision matrix. The weighted normalized predictive value, $v_{ij}$, is calculated as

$$v_{ij} = w_j r_{ij}, \ \sum_{j=1}^{4} w_j = 1, \ i = 1,\ldots,9, \ j = 1,\ldots,4 \quad (4)$$

where $r_{ij}$ is the normalized predictive values and $w_j$ is the weight of the *j-th* UIP. As an illustration, icon designer can assign the value of 1-7 as well as a 7-point Likert scale. For example, the intensely "Vigorous" is assigned the value of 6, a little bit "Sprightly" is 2, somewhat "Formal" is 3, and quite a bit "Elegant" is 5. Consequently, the normalized weights are 0.375(6/16), 0.125(2/16), 0.188(3/16) and 0.313 (5/16), respectively.

Step 4: determine the positive and negative ideal alternatives. Note that the positive ideal alternative represents the set of best performances at each UIP, expressed by $A^+$, while the negative alternative represents the set of worst performances, expressed by $A^-$, respectively, as

$$A^+ = \{ v1^+, v2^+, v3^+, v4^+\} \quad (5)$$

and

$$A^- = \{ v1^-, v2^-, v3^-, v4^-\}. \quad (6)$$

In the current illustration, positive ideal alternative $A^+$ = (0.0758, 0.0253, 0.0460, 0.0577) and negative ideal alternative $A^-$ = (0.0429, 0.0163, 0.0177, 0.0365), respectively.

Step 5: calculate the distance from each experimental sample to the positive ideal alternative, $D^+$, and the distance from each experimental sample to the negative ideal alternative, $D^-$. The positive ideal alternative, $D_i^+$ and the negative ideal alternative, $D_i^-$ are calculated, respectively, from

$$D_i^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^+)^2}, \quad i = 1, \ldots, 9 \quad (7)$$

and

$$D_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2}, \quad i = 1, \ldots, 9 \quad (8)$$

Step 6: the satisfiability index (SI) of each static icon sample is calculated as follows

$$SI_i = \frac{D_i^-}{D_i^- + D_i^+}, \quad i = 1, \ldots, 9 \quad (9)$$

Based on the CA models described in the "Utility" column of each UIP descriptor of **Table 4**, the predictive values of 9 icon samples are calculated and normalized across all of the UIPs. The weighted predictive values are then calculated for each UIP descriptor by applying the weight decision matrix (i.e. vigorous 0.375; sprightly 0.125; formal 0.188; and elegant 0.313). The corresponding results are summarized in **Table 5**, which also shows the results calculated for the distance between each sample and the positive ideal alternative ($D^+$), the distance between each sample and the negative ideal alternative ($D^-$), and the satisfiability index (SI) of each icon sample.

**Table 5.** Calculated results of weighted CA model predictive value, $D^+$, $D^-$, and *SI*

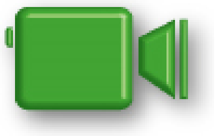
| Icon Sample | Weighted predictive value of CA model | | | | $D^+$ | $D^-$ | *SI* |
|---|---|---|---|---|---|---|---|
| | Vigorous | Sprightly | Formal | Elegant | | | |
| 1 | 0.049 | 0.016 | 0.036 | 0.042 | 0.034 | 0.175 | 0.839 |
| 2 | 0.066 | 0.023 | 0.030 | 0.052 | 0.020 | 0.240 | 0.923 |
| 3 | 0.055 | 0.022 | 0.018 | 0.050 | 0.036 | 0.178 | 0.831 |
| 4 | 0.076 | 0.017 | 0.044 | 0.039 | 0.021 | 0.250 | 0.923 |
| 5 | 0.076 | 0.024 | 0.037 | 0.037 | 0.023 | 0.245 | 0.914 |
| 6 | 0.043 | 0.024 | 0.025 | 0.047 | 0.040 | 0.163 | 0.801 |
| 7 | 0.062 | 0.025 | 0.021 | 0.057 | 0.029 | 0.228 | 0.887 |
| 8 | 0.061 | 0.021 | 0.046 | 0.058 | 0.015 | 0.270 | 0.946 |
| 9 | 0.063 | 0.021 | 0.023 | 0.042 | 0.031 | 0.189 | 0.858 |

Step 7: evaluates the utility of each level of each attribute upon the SI. The calculation of the utility of the *i-th* level of the *j-th* attribute is performed by summing the SIs of all the icon visual effect conditions involving the *i-th* level of the *j-th* attribute and then dividing the result by the number of SIs.

Step 8: the level of each attribute which has the greatest utility upon the SI is selected to establish the optimal set of attribute level settings for the visual effect of static icon.

**Table 6** presents the utility of each level of each attribute and the overall importance of each attribute. An optimal set of static icon parameters can be established by taking the highest utility level of each attribute for developing the optimal design of icon visual effect, i.e. the optimum of icon visual effect can consider the following effect features (level) including the feature of Gradual-shadow effect ($X_{13}$), the Non-Perspective effect ($X_{21}$), Round-edge Stereo-effect ($X_{33}$), and the Non-Frame effect ($X_{41}$). The influence of each attribute to multiple UIPs is identified by the "attribute importance" column of **Table 6**. Hence, it is found that the “Stereo-effect (46.2%)” has the obvious influence on the UIP to the visual effect of static icon, while the “Frame effect with reverse type fill-color (11.3%)” has the slight effect in the current study.

**Table 6.** Optimization of icon visual effect for the multiple UIPs

| Attribute | Level | | | Attribute importance | Optimum of icon visual effect for matching multi-UIPs |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | | |
| $X_1$ | 0.862 | 0.880 | **0.900*** | 0.203 |  |
| $X_2$ | **0.903*** | 0.861 | 0.877 | 0.222 | |
| $X_3$ | 0.824 | 0.906 | **0.911*** | 0.462 | $X_{13}$ (gradual-shadow effect)<br>$X_{21}$ (non-perspective effect) |
| $X_4$ | **0.892*** | 0.871 | 0.878 | 0.113 | $X_{33}$ (round-edge stereo effect)<br>$X_{41}$ (non-frame effect) |

## VALIDATION

To verify the effectiveness of the integrated design approach, three new icon samples for verification purpose are subjectively created by 3 designers with more than three years' experience in interface design to meet the requirements of 4 UIP Descriptors (i.e. the intensely Vigorous, a little bit Sprightly, somewhat Formal, and quite a bit Elegant) by means of manipulating the attributes and the corresponding levels shown in **Table 1**. **Figure 3** shows the three new icon samples (NISs).

NIS. 1 NIS. 2 NIS. 3

**Figure 3.** Three new icon samples (NISs) for verification purpose

In the verification process, four verification samples including the three new icon samples(NISs) and the optimal icon design sample(OIDS) shown in the rightmost column of **Table 6** are input to the evaluative interface shown in **Figure 2**, and are then evaluated by a group of 30 subjects (18 male, 12 female) using four 7-point Likert scales. Furthermore, the requirements of 4 UIP Descriptors are assigned to the target value of optimal icon design (TVOID) for static icon visual effect (i.e. the intensely Vigorous is 6, a little bit Sprightly is 2, somewhat Formal is 3, and quite a bit Elegant is 5). The discrepancy between the target value of optimal icon design (TVOID) and the 7-point Likert scale evaluation values assigned to each verification sample by the 30 subjects is assessed using the following root-mean-square-discrepancy index (abbreviated for convenience hereafter to DI):

$$DI = \sqrt{\frac{\sum_{i=1}^{n}(x_i - x_o)^2}{n}} \qquad (10)$$

where $x_i$ is the 7-point Likert scale point assigned by the *i-th* subject, $x_0$ is the target value of optimal icon design (TVOID), and $n$ is the number of subjects involved in the validation experiments (i.e. thirty in the current case). The DI value in Eq. (10) gives the average discrepancy between the subjects' evaluations regarding the four verification samples and the target value of optimal icon design (TVOID), respectively, for a single point on the 7-point Likert scale. A normalized DI value is obtained by dividing the result obtained from Eq. (10) by seven to yield a discrepancy rate (DR) in the interval [0, 1] to enable the difference between the evaluation of the OIDS and those of the NISs to be more conveniently compared. Clearly, a lower value of DR indicates a closeness which more closely matches the target value of optimal icon design in terms of a designated UIP toward the static icon visual effect.

**Table 7** summarizes the statistical results of the four UIP domains associated with the four icon verification examples. In this table, the first and second columns show the mean and standard deviation (SD) of the evaluation data acquired for each sample in each of the four UIP domains, respectively. Meanwhile, the third and rightmost columns indicate DI values and the corresponding discrepancy rate (DR) values for each verification sample, respectively. From inspection, the DR values of the four UIP domains associated with the OIDS vary from 10.8% (elegant) to 15.6% (sprightly). By contrast, these DR values of the four UIP domains associated with the other three NIS are found to vary from 12.5% (vigorous) to 44.2% (sprightly) for the NIS.1, to vary from 10.8% (elegant) to 25.8% (sprightly) for the NIS.2, and to vary from 10.4% (vigorous) to 32.1% (sprightly) for the NIS.2, respectively. The results presented in **Table 7** show that the DR values of the OIDS are lower (i.e. better) than those of the other three NISs in most of the UIP domain. The only exception to this tendency occurs in the "Vigorous" image perception domain, in which the DR value of the OIDS (13.3%) is slightly higher than that of the NIS.1 (12.5%), NIS.2 (11.7%) and NIS.3 (10.4%). Further, the DR values of four verification samples are respectively calculated the average DR so as to examine the effectiveness of considering the whole of multiple UIP by comparing the average DR of the OIDS with the DR values of the three NISs. Observing the average DR data presented in the lower row of **Table 8**, the average DR value of the OIDS (13.4%) is consistently lower than that of the NIS.1 (26.4%), NIS.2 (16.8%) and NIS.3 (17.6%). It is thereby inferred that the OIDS created by using the integration of CA with TOPSIS algorithm represent a better solution for matching the whole of multiple UIP responses to a particular icon visual effect than the other three NISs.

**Table 7.** Manually assigned icon visual effect evaluation data and discrepancy rate (DR) analysis

| | **Vigorous (TVOID=6)** | | | |
|---|---|---|---|---|
| | **Mean** | **SD** | **DI** | **DR** |
| **OIDS** | 5.667 | 0.884 | 0.931 | 13.3% (0.931 / 7) |
| **NIS.1** | 5.633 | 0.809 | 0.876 | 12.5% (0.876 / 7) |
| **NIS.2** | 6.067 | 0.828 | 0.816 | 11.7% (0.816 / 7) |
| **NIS.3** | 5.933 | 0.740 | 0.730 | **10.4% (0.730 / 7) *** |

| | **Sprightly (TVOID=2)** | | | |
|---|---|---|---|---|
| | **Mean** | **SD** | **DI** | **DR** |
| **OIDS** | 2.533 | 0.973 | 1.095 | **15.6% (1.095 / 7) *** |
| **NIS.1** | 4.967 | 0.890 | 3.093 | 44.2 % (3.093 / 7) |
| **NIS.2** | 3.533 | 0.973 | 1.807 | 25.8 % (1.807 / 7) |
| **NIS.3** | 4.033 | 0.964 | 2.244 | 32.1 % (2.244 / 7) |

| | **Formal (TVOID=3)** | | | |
|---|---|---|---|---|
| | **Mean** | **SD** | **DI** | **DR** |
| **OIDS** | 3.333 | 0.922 | 0.966 | **13.8 % (0.966 / 7) *** |
| **NIS.1** | 2.167 | 0.874 | 1.197 | .17.1 % (1.197 / 7) |
| **NIS.2** | 3.933 | 0.944 | 1.317 | .18.8 % (1.317 / 7) |
| **NIS.3** | 3.667 | 0.959 | 1.155 | .16.5 % (1.155 / 7) |

| | **Elegant (TVOID=5)** | | | |
|---|---|---|---|---|
| | **Mean** | **SD** | **DI** | **DR** |
| **OIDS** | 4.900 | 0.759 | 0.753 | **10.8 % (0.753 / 7) *** |
| **NIS.1** | 2.933 | 0.868 | 2.236 | 31.9 % (2.236 / 7) |
| **NIS.2** | 5.233 | 0.728 | 0.753 | **10.8 % (0.753 / 7) *** |
| **NIS.3** | 5.167 | 0.791 | 0.796 | 11.4 % (0.796 / 7) |

Asterisks indicate that DR value of verification sample is lower (i.e. better).

**Table 8.** Comparison of average DR values

| | **OIDS** | **NIS.1** | **NIS.2** | **NIS.3** |
|---|---|---|---|---|
| Vigorous | 13.3% | 12.5% | 11.7% | 10.4% |
| Sprightly | 15.6% | 44.2% | 25.8% | 32.1% |
| Formal | 13.8% | 17.1% | 18.8% | 16.5% |
| Elegant | 10.8% | 31.9% | 10.8% | 11.4% |
| Average DR | 13.4 % | 26.4% | 16.8% | 17.6% |

## DISCUSSION AND CONCLUSION

In an attempt to match multiple UIP requirements, this study has proposed an integrated design approach combining the CA and the TOPSIS algorithm to develop the multi-objective icon visual effect design in the current study. A series of evaluation trials with the visual effect of static icon have conducted to illustrate the implementation procedure of integrating CA with TOPSIS algorithm, and demonstrated the ability of the integrated design approach to not only match the multiple UIP requirements, but also generate an optimized icon visual effect. Comparing the integrated design approach with those traditional KE approaches (e.g., Tung et al., 2009; Lin et al., 2013; Chen and Chang, 2016), one of the conspicuous difference lies in their respective intentions. The integrated design approach based on CA with TOPSIS algorithm is to obtain a set of suitable design parameters to satisfy the multiple UIP for the visual effect of static icon, whereas the KE approaches is to construct an accurate model to describe or predict the possible UIP to the visual effect of static icon using the specific analysis techniques, e. g., Quantitative Theory Type I (QTT1), Multiple Regression Analysis (MRA), back-propagation neural network (BPNN) and so on. In addition, the KE approaches commonly depend upon a large number of samples to ensure their accuracy, the current integrated approach requires fewer evaluation samples and a lesser number of investigative scales. Hence, the current integrated approach reduces the time and cost required to complete the subjective evaluations of icon image perceptions. These advantages enable the integrated approach to develop an emotional icon design. For example, the integrated approach can be employed to redesign existing static icons in order to enhance their aesthetic appeal, or to develop a new series of static icons which still maintains the form of existing static icon by means of changing the visual effect of a static icon.

Notwithstanding the integrated design approach has the superiority in matching the multiple UIP requirements of an icon, the CA with TOPSIS algorithm has certain limitations when applied to design a static icon. The basic point in applying the current integrated method is to identify the attributes and their corresponding levels which have a significant influence on UIP to the visual effect of an icon. In other words, the appropriate selection of the attributes and their levels has a crucial influence on the efficiency of the current integrated approach. For example, in this case study, 4 attributes of the icon visual effects were selected in accordance with the discussion of five design experts. If attributes or levels with a lesser influence had been selected, it is possible that the UIP of icon visual effect might not have been enhanced substantially through the current integrated approach. Consequently, when wishing to use the CA with TOPSIS algorithm-based approach, it is first advisable to conduct a thorough pilot study to identify the most influential attributes or levels before performing the relevant design assignment. In conclusion, the results obtained in this study confirm the feasibility of the integrated design approach based on CA and TOPSIS algorithm. Furthermore, the proposed approach also provides an efficient means of assessing icon visual effect for the development of icon design on the form of scientific basis. In future studies, the generality of the current integrated approach could be extensively investigated by considering a variety of static icon or dynamic icon examples.

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