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A semantic differential study of designers' and users' product form perception

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Abstract

This study investigated the differences in the product form perception of designers and users. The semantic differential (SD) method was employed to examine the relationship between the subjects' evaluation of telephone samples and form design elements. The authors used 14 image-word pairs for the evaluation of telephone design. The format for a measurement scale was constructed by a projection method in order to extract design attributes for an SD test. Twenty-four real telephone samples were presented to 40 subjects (20 designers and 20 users) for subjective evaluation. Multivariate analyses were performed to analyze the subject's perceptions and to build conceptual models for telephone design. The result revealed that many differences exist between designers' and users' perceptions of the same real objects and their interpretations of the same image-words. Users are not clear regarding the meaning of the image-words. Moreover, they are very concerned about whether a telephone looks new. Designers tend to value telephone samples with an elegant style while users prefer modern and sleek designs. The conceptual models of the two subject groups are made up of different components. Creative, mature, delicate design images play a greater role in affecting the designers' preference while the users' preference is affected mainly by images of delicacy. The implications of differences in preference and the relationship between image-word and actual design elements for the two subject groups are discussed.

Relevance to industry

It is the users' needs and preferences, not those of the designers, that should be taken into consideration during the product design process. Due to the fact that many differences exist between designers and users, it is a challenge for designers to transfer the consumer's needs into technical and design specifications. Quantitative data on the relationship between design elements and user evaluations is useful to product designers and managers in formulating design strategies.

Keywords: Product semantics; Kansei engineering; Conceptual model; Semantic differential method

1. Introduction

The current trend in product design has shifted from functionalism (form follows function) to product semantics (form follows meaning) (Krippendorff, 1995). According to this trend, the users'

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needs and preferences are primary concerns in product development within a highly competitive market. In order to meet the users' needs, designers have to make explicit the connotative and denotative meanings (Lin et al., 1996) of their products. It is, however, still not clearly understood how users perceive a product form and how the meaning of the product form can be effectively transmitted to them. This is due to the fact that the users' feeling about the product is a very complex cognitive process and many intricate factors contribute to the perception of a product form.

To investigate the users' perception of product form, the semantic differential method (SD) (Osgood et al., 1957) is one of the most frequently used procedures. In this method, which studies product semantics, the subject's perception of product forms is quantified on a Likert scale. Many researchers have used this method to study specific aspects of product form, including styles, colors, and other attributes in product design. For example, Maurer et al. (1992) conducted a study on the form of street furniture and explored the dimensions upon which the subject's judgment was based. Moreover, Espe (1992) performed an image study on the symbolic quality of watches and identified three judgment dimensions; namely, material and social representation, functional and logical representation, and aesthetic representation. These results provide the analytic support for designers and product managers.

In addition, much research has been performed under the name of Kansei Engineering, an ergonomic consumer-oriented technology for new product development (Nagamachi, 1995,1996). Product designers in a variety of areas have taken such computational approaches. Among these are image technology (Jindo et al., 1995; Hsiao and Chen, 1997), neural network theory (Ishihara et al., 1995, 1996, 1997), and fuzzy set theory (Chang and Mori, 1993; Seo et al., 1996; Shimizu and Jindo, 1995; Tsuchiya et al., 1996). These studies quantify people's perceptions about the product form and translate a consumer's perceptions into the design elements. The results have demonstrated that this approach is applicable to many areas. Nevertheless, the mechanism of the users' conceptual model in perceiving a product, especially the phenomenon of the differences between individual perceptions and actual products and means of verification of such models, has not been fully explored.

Regarding the conceptual model of the product, Krippendorff argued that the designers' objectified meaning, which is built into the product form, is not presumed to be the same as the product's meaning in the users' eyes (Krippendorff, 1995). Such a mismatch will bring failure to a high-tone design. Moreover, general users do not appreciate the artistic style of some design award winners. It is, therefore, necessary to study how designers' and users' conceptual models are related in the terms of product semantics.

The purpose of this study is to investigate the differences between designers and users in perceiving product form. To quantify the users' perceptions, the relation between image-words and the design elements of telephone samples was examined. Moreover, the relationship between particular design elements and image-word values was clarified quantitatively to determine what designers and users perceive and which impressions are created by the design elements of a product form. Design factors and levels of product design that have a strong influence on specific image-words were extracted and compared.

2. Method

The research project can be divided into two stages, Stages I and II as summarized in Table 1. In Stage I, a projection method was used to extract the design attributes and a small-scaled preliminary test was conducted to construct the evaluation format. The evaluation adjectives and representative telephone samples obtained from Stage I were used in the SD test of Stage II where the relationships between design attributes and users' perceptions were explored.

2.1. Stage I – preliminary test

One of the most difficult tasks in identifying the users' perception of product form is to see how they grasp the image of a product in terms of psychological estimation. To elicit the subject's feeling

Table 1
Stages of the research

	Stage I		Stage II
	Extracting design attributes	Verification of the measurement scale	Semantic differential test
Purpose	To identify the evaluation adjectives and the design elements	To choose the representative telephone samples and adjectives	To study users' preference and to build up their conceptual model
Subjects	Designers : 17 Users : 17	Senior designers : 5	Designers : 20 Users: 20
Material	Questionnaires with 10 telephone samples	Questionnaires with 30 telephone samples and 24 adjectives	Questionnaires with 24 telephone samples and 14 adjectives
Task	Thinking aloud	SD evaluation	SD evaluation
Analytical tool	Keyword analysis	Cluster analysis	Linear regression, paired *T*-test, factor analysis, conjoint analysis

Fig. 1. The 10 sample telephones for Stage I research.

about a product, a projection method was used to extract the image-words and the design elements the subjects used to describe their perceptions about the telephone samples. Twenty-four image-word pairs and 30 real telephone samples were then employed in a subjective evaluation test at this stage to verify the measurement scale for the SD test.

2.1.1. Extracting design attributes

Subjects: The subject sample used at this stage included 17 designers and 17 users. The designer group consisted of 11 males and 6 females. They were 21–40 yr old and with the educational background from college to graduate school. The user subjects represented the telephone user population. They included 9 males and 8 females. They were of the age from 20 to 50 and of the educational background from senior high to graduate school.

Material: The questionnaires at this stage were made up of 10 telephone images and questions which stimulated the subject to use the adjectives and design elements to express their perceptions about the 10 scanned images of telephones (Fig. 1).

Procedure: Each subject was asked to look at the telephone samples and verbally express his or her perceptions about the telephone image. The descriptions of their perceptions were recorded for later analysis.

Results: A keyword analysis of the adjective and design elements was calculated. The adjective pairs with higher distribution frequency were then integrated and classified. At last, 24 adjective-and-antonym pairs (Table 2) were chosen for the measurement scale.

2.1.2. Constructing the evaluation format

Subjects: To select the representative telephone samples and the evaluation adjectives used later in conducting subjective evaluations of different telephones, five senior designers, whose average design

Table 2
The 24 image word pairs used in the pilot test

traditional – modern	rectangular – rounded	hard – soft	old – new
large – compact	heavy – handy	obedient – rebellious	nostalgic – futuristic
coarse – delicate	masculine – feminine	rational – emotional	hand-made – hi-tech
childish – mature	unoriginal – creative	simple – complicated	conservative – avant-garde
standard – outstanding	common – particular	plain – luxurious	decorative – practical
inert – active	personal – professional	obtuse – brilliant	discordant – harmonious

Table 3
The 14 image word pairs used in the SD test

traditional – modern	heavy – handy	hard – soft	nostalgic – futuristic
large – compact	masculine – feminine	obedient – rebellious	hand-made – hi-tech
coarse – delicate	unoriginal – creative	rational – emotional	conservative-avant-garde
childish – mature	common – particular		

experience was more than 10 years, participated in the pilot test.

Material: 24 adjective pairs (in Chinese) obtained from the preliminary test and 30 real telephone samples picked out of 50 telephone samples by two experienced product designers were used to identify typical image words and telephone design elements.

Procedure: Each subject was asked to evaluate these 30 telephones according to a single adjective pair on a 9-point scale (refer to the SD test for detailed explanation of the attitude scale and the procedure). Subjects were allowed to do the test at their own pace.

Results: The data were then coded for cluster analysis. Considering the tradeoff between the number of evaluation tasks and the precision of performance requirement, a cut-off point in the hierarchical tree diagram of the cluster analysis was chosen from which 14 adjective pairs (Table 3) and 24 sample telephones (Fig. 2) were picked for the semantic differential test.

2.2. Stage II – Exploring designers' and users' perceptions about product form

The SD method was used to explore the designers' and users' perceptions about product form. The data obtained were then quantified to build up a design reference model of designers and users.

Subjects: 40 subjects (20 designers and 20 users, most of whom are the same subjects as those of Stage I) participated in the subjective evaluation task.

Material: 24 real telephones and 14 image words (in Chinese) were used for the SD test. In this test, image and preference perception were scored according to a 9-point scale. A bipolar pair of descriptive adjectives defines the attribute scale, with the positive word on the right and its negative counterpart (antonym) on the left. On this evaluation scale, a score of 9 points means that the subject has a very strong positive impression of the sample, while 1 point means a very strong negative impression.

Procedure: The test was performed on a small group. First impressions of the sample telephone were stressed in the test. The evaluations were conducted individually and each subject was allowed to proceed at his or her own pace. At the end of the test, the subjects were asked to express their preferences regarding these telephone samples. The test was undertaken in a big room in which each sample telephone was placed on the central part of a drafting table. The subjects walked around the samples

Fig. 2. The 24 real telephone samples in the SD test.

to view them thoroughly and then evaluated them on the basis of their impressions. They were allowed to assess the telephone samples in random order. To avoid interference in evaluating the telephone samples, the subjects were asked not to talk to each other during the test.

3. Results and discussion

The raw evaluation data and preference scores of the designers and users were analyzed primarily with regard to the following points:

(1) Evaluation and preference score distribution;
(2) Factor analysis (principal component analysis) of the subject's perceptual space;
(3) Relative importance of design elements;
(4) Design reference model.

3.1. Distribution of the raw data

The raw data – mean scores and standard deviation – for the 14 adjective pairs rated by designers and users reflected that the designer is better able than the user to tell one product form from another. Because the users are not clear about the product form, they tend to give the telephone sample a mid-scale evaluation. For example, the range of

designers' perceptions of the image "modern" is 5.80, while that of the users is 3.80. The smaller range means that it is more difficult for the user to distinguish the subtle differences in product forms.

It is the same for the raw data on the preference scores of the two subject groups. The designers and users are different in their preference distribution patterns. The range of designers' preference scores is 5.05 and that of users is 4.20. Therefore, one can conclude that designers are more sensitive and clearer than the users regarding the product form.

3.2. The preference distributions

The preference score is an important index to reflect the extent to which a product attracts the consumer. The rankings of the most preferred telephone samples were compared to identify the designers' and users' preference pattern. Moreover, the raw data for all telephone samples' preference scores were analyzed by a paired T-test to see if there existed significant differences between the two groups.

The results revealed that the two groups of subjects are significantly different in their perceptions of 12 out of 24 telephone samples as reflected in their preference: T4, T5, T7, T8, T11, T13, T14, T15, T17, T21, T22, T23 (P value < 0.05). However, designers and users are similar in their perceptions of telephone samples T6 ($P = 0.741$), T24 ($P = 0.849$), T10 ($P = 0.365$) and T19 ($P = 0.379$). Some sample telephone designs, T5, T8, and T21, for instance, are preferred by designers but not favored by users. Similarly, telephone samples T4 and T11, two telephone designs with a modern style, are preferred by the users but not highly favored by the designers. This means that the majority of users may not appreciate a product which the designers view as elegant or as having a good design style.

3.2.1. The designers' and users' preference patterns

The average preference scores revealed that there is a difference between designers and users in their assessment of these telephone samples. Fig. 3 shows the most preferred telephones of designers and users. It is found that designers have a preference tendency toward modern and hi-tech telephones, and those with a sense of elegant European style (3 of the designers' 5 most preferred telephones, T5, T9, and T21, have a strong image of such a style), while users prefer the modern and entertaining telephones, a style that embodies pleasure and delight. As for the most preferred telephones, both groups favor Samples T19 and T20. These results indicate that the sleek modern image of a lean, curvilinear structure will be the most popular for the majority of people.

Among these most preferred samples, T5 is a special case. It is one of the most desirable telephones in the designers' eyes (preference = 7.00). However, it is not much preferred by the users (preference = 3.60). The image profile of sample T5 is shown in Fig. 4, where significant differences can be seen for 10 out of 14 image words (P

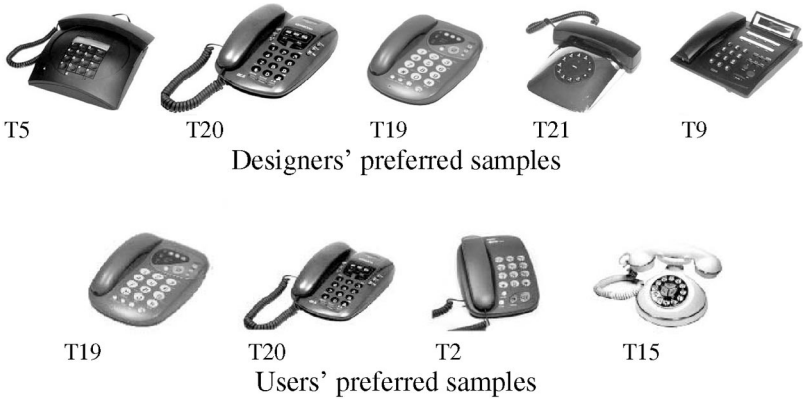


Fig. 3. Designers' and users' most preferred telephone samples.

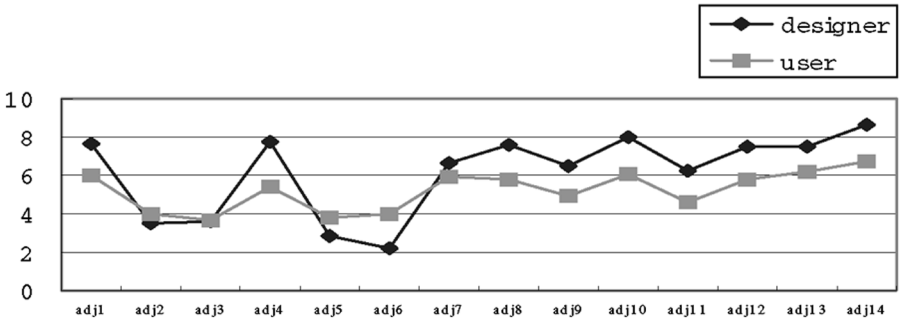


Fig. 4. The image profile of T5 (preference = 7.00 (designers), and 4.80 (users)).

values < 0.05 in paired T-test). For sample T5, the designers and users are similar in their evaluation of the image-words "handy," "soft," "compact," and "rebellious." Because preference is based on a mixture or interaction of all sorts of perceptions, the discrepancy in the image perceptions causes the two groups to be different in their final product form preference.

3.2.2. The relationship between preference and image word

A linear regression analysis was performed to examine the relationship between the preference score and the evaluation adjective. The result shows that, in the designers' case, all evaluation adjectives except "feminine" have a positive correlation with the preference score (Table 4). In the users' case, all the correlation coefficients are positive.

In the designers' case, the image perceptions most relevant to preference assessment are "modern," "futuristic," "rebellious," "hi-tech," "delicate," "creative," "avant-garde," and "mature." The Pearson's coefficients for the relation between preferences and image perceptions are higher than 0.8. In the users' case, only the image word "delicate" ($r = 0.807$) has a high correlation with preference. From Table 4, it can be seen that these two groups are different in their use of the image-words "soft," "futuristic," "feminine," "rebellious," and "mature." The two subject groups are similar regarding the image-words "delicate" and "particular" in terms of correlations and linear functions.

In addition, a stepwise multiple regression analysis was performed to examine the relationship between preference and image perceptions. The results showed that the two groups are different in their semantic structure for preference. Their preferences can be expressed as Functions (1) and (2), respectively.

$$\tilde{Y}_{\mathrm{d}} = -2.598 + 0.323X_{10} + 0.540X_{13} + 0.488X_{9}\ \text{(designers)}, \quad (1)$$

$$\tilde{Y}_{\mathrm{u}} = -0.263 + 0.980X_{9}\ \text{(users)}, \quad (2)$$

where X_{10} represents the evaluation score for the "creative" image; X_{13} represents the evaluation score for the "mature" image; X_{9} represents the evaluation score for the "delicate" image.

The functions show that the "creative," "mature," and "delicate" images are the most important ones in influencing the designers' preference. For the users, "delicacy" is the only dominant image affecting their preference.

3.3. The principal components of the designers' and users' perceptual space

Though the telephone images can be represented in a perceptual space where each evaluation adjective has an independent dimension, it is too complicated to figure out the relative location of each telephone sample in such a 14-dimensional semantic space. Moreover, it is not known whether there exists any interaction among these image words. A factor analysis, therefore, was performed on the numerical scores assigned to the 14 evaluation adjectives.

According to Osgood (1957), people's perception of objects can be divided into three main factors:

Table 4
Regression model for the preference of designers and users. (Y_i vs. X_i, Y = preference score, X = mean score of the evaluation adjective, $i = 1, \ldots, 14$)

Image words	Designers		Users	
	Correlations	Linear function	Correlations	Linear function
Modern	0.862	$\tilde{Y}_d = 0.623 + 0.778X_1$	0.672	$\tilde{Y}_u = 1.233 + 0.676X1$
Handy	0.267	$\tilde{Y}_d = 3.017 + 0.306X_2$	0.481	$\tilde{Y}_u = 2.058 + 0.511X_2$
Soft	0.232	$\tilde{Y}_d = 3.439 + 0.226X_3$	0.723	$\tilde{Y}_u = 1.136 + 0.758X_3$
Futuristic	0.840	$\tilde{Y}_d = 0.887 + 0.718X_4$	0.400	$\tilde{Y}_u = 2.535 + 0.420X_4$
Compact	0.099	$\tilde{Y}_d = 3.929 + 0.105X_5$	0.506	$\tilde{Y}_u = 1.801 + 0.534X_5$
Feminine	−0.305	$\tilde{Y}_d = 5.745 - 0.286X_6$	0.371	$\tilde{Y}_u = 2.664 + 0.350X_6$
Rebellious	0.864	$\tilde{Y}_d = 0.340 + 0.952X_7$	0.492	$\tilde{Y}_u = 2.171 + 0.526X_7$
Hi-tech	0.883	$\tilde{Y}_d = 0.793 + 0.768X_8$	0.508	$\tilde{Y}_u = 2.044 + 0.525X_8$
Delicate	0.860	$\tilde{Y}_d = -1.095 + 1.110X_9$	0.827	$\tilde{Y}_u = -0.263 + 0.980X_9$
Creative	0.911	$\tilde{Y}_d = -0.222 + 0.931X_{10}$	0.619	$\tilde{Y}_u = 1.357 + 0.665X_{10}$
Emotional	0.299	$\tilde{Y}_d = 2.904 + 0.321X_{11}$	0.668	$\tilde{Y}_u = 1.259 + 0.664X_{11}$
Avant-garde	0.897	$\tilde{Y}_d = 0.155 + 0.871X_{12}$	0.590	$\tilde{Y}_u = 1.259 + 0.653X_{12}$
Mature	0.842	$\tilde{Y}_d = -2.144 + 1.189X_{13}$	0.158	$\tilde{Y}_u = 2.775 + 0.303X_{13}$
Particular	0.652	$\tilde{Y}_d = 1.249 + 0.592X_{14}$	0.634	$\tilde{Y}_u = 0.937 + 0.660X_{14}$

evaluation, potency, and activity factors. In the study, the descriptive adjectives for each factor were shown in Tables 5 and 6 for the two subject groups. Three factors were extracted with a cumulative contribution rate of 90.4% for the designers, and three factors with a cumulative contribution rate of 85.1% were found for the users.

3.3.1. *The designers' perceptual space*

For the designers, the first factor axis is related to the telephone design and can be represented by such adjectives as "creative," "avant-garde," "hi-tech," "modern," "futuristic," "rebellious," "mature," "delicate," and "particular," which can be defined as the evaluation factor. The second axis indicates the sense of power conveyed by the telephone shape, as expressed by such adjectives as "soft," "feminine," and "emotional". This can be defined as the shape (potency) factor. The third axis is related to the way people feel about operating a telephone and can be defined as the activity factor. Typical image words such as "handy" and "compact" can be used to represent this factor. These three factor axes represent the main visual criteria by which designers typically evaluate their telephone samples.

Table 5 shows the typical descriptive adjectives and telephone samples from the designers' point of view. The typical positive telephone samples are the ones whose factor scores are greater than 1.0 in the factor axis, while the typical negative samples have factor scores below −1.0.

3.3.2. *The users' perceptual space*

The 14 dimensions of the users' perception of telephone design can be simplified down to three factors. As with the designers, the users' first factor axis can be defined as an evaluation axis. Image words such as "particular," "creative," "emotional," "rebellious," "avant-garde," and "delicate" are typical for this axis. The second axis signifies the visual impressions of the time or period in which the telephone was made, expressed by such adjectives as "traditional," "futuristic," "hi-tech," and "modern," and can be defined as the time factor. The third axis includes design factors related to shape and activity. Typical image-words include "feminine," "compact," "mature," "handy," and "soft." These three factor axes contribute the main visual criteria by which users commonly judge the worth of telephones. Table 6 lists typical descriptive adjectives and telephone samples (factor scores > 1.0 or < -1.0) from the users' point of view.

Table 5
Three principal factors for designers

Factors for designers	Typical descriptive adjectives	Pct of Var	Typical telephone samples (positive)	Typical telephone samples (negative)
Factor 1 evaluation factor	Creative, avant-garde, hi-tech, modern, futuristic, rebellious, mature, delicate, particular	55.2%	T5, T9, T19, T20, T21	T3, T7, T13, T15
Factor 2 shape (potency) factor	Emotional, soft, feminine	24.4%	T6, T15, T18	T3, T8, T9, T10, T13, T16
Factor 3 activity actor	Handy, compact	10.8%	T1, T14, T16	T3, T5, T17

Table 6
Three principal factors for users

Factors for users	Typical descriptive adjectives	Pct of Var	Typical telephone samples (positive)	Typical telephone samples (negative)
Factor 1 evaluation factor	Particular, creative, emotional, rebellious, avant-garde, delicate	55.7%	T5, T15, T17, T18, T19, T20	T1, T3, T8, T13
Factor 2 time factor	Futuristic, hi-tech, modern	18.4%	T9, T19, T20	T3, T15, T17
Factor 3 shape and activity factor	Feminine, compact, mature, handy, soft	10.9%	T11, T12, T14, T18	T5, T9, T10, T17, T23

As we see from Tables 5 and 6, designers and users show a similar semantic structure only for factor 1, the evaluation factor axis that explains about 50% of the total variance. Their interpretations, however, are not the same, as reflected in the typical image-words in the factor axis. The other two factors, however, are different in terms of their construction.

A close look at the components shows that, in terms of impact on preference, the users' factor 3 (shape and activity factor) is nearly equal to the sum of the designers' factor 2 (shape factor) and factor 3 (activity factor) and that designers' factor 1 (evaluation factor) is nearly equal to the sum of the users' factor 1 (evaluation factor) and factor 2 (time factor). This confirms our finding that the designer is more sensitive and discriminating with regard to product form than the user. What the users think of as a single shape-and-activity factor is divided into shape and activity factors by the designers. Moreover, the users are very concerned about whether a telephone design is new- or old-looking. The designers' evaluation factor, therefore, is divided into evaluation and time factors in the users' case.

With preference and factor scores for the telephone samples, a multiple regression analysis was performed to check the correlations between the two subject groups' preferences and the components of their perception. The results show that the preferences of designers and users can be expressed with Formulas (3) and (4):

$$\tilde{Y}_{\mathrm{d}} = 4.429 + 1.364\,(\text{evaluation factor}) - 0.026\,(\text{shape factor}) + 0.151\,(\text{activity factor}); \quad (3)$$

$$\tilde{Y}_{\mathrm{u}} = 4.448 + 0.638\,(\text{evaluation factor}) + 0.403\,(\text{time factor}) + 0.300\,(\text{shape and activity factor}). \quad (4)$$

The Pearson correlation coefficients for designers' preference/factors are 0.935, -0.018, and

0.104 for the evaluation, shape and activity factors. This means that the evaluation factor has more effect than the shape and activity factors on designers' preference assessment of telephone design. The negative correlation shows that "emotional," "soft" or "feminine" images will decrease the degree of preference perception. This confirms that the correlation between designers' preferences and the "feminine" image is negative.

For the users, the correlations between preference and the component factors are 0.589, 0.372, and 0.277 for the evaluation, time and shape factors. The degrees of correlation reflect the percentage of each factor's contribution to the total variance. The evaluation factor plays the most important role in affecting both the designers' and users' preference assessment.

3.3.3. *Visualizing the subjects' perceptual space*

From the profile of the product perception of designers and users, based on the evaluation scores, one can see the differences between the two subject groups. Besides, their differences can be illustrated by the factor scores to explore the distribution pattern in the perceptual space of telephone samples.

To compare designers and users in terms of their image perception, the average evaluation scores of the two subject groups went into a joint factor analysis. The results show that the perception structure of all subjects (total subject group) could be categorized into three factors (Table 7). The factor scores for the same telephone sample in the two groups were compared in terms of each factor axis.

The factor scores of the 24 products evaluated in the SD survey can be calculated and treated as coordinates in a perceptual space. By mapping these 24 points into this space, the distances between factor axes were computed. Moreover, the relative semantic distance (d_i) between designers and users in the perceptual space was calculated by the following formula:

$$d_i = \sqrt{(x_d - x_u)^2 + (y_d - y_u)^2 + (z_d - z_u)^2},$$

where x_d = designers' factor 1 score, y_d = designers' factor 2 score, z_d = designers' factor 3 score; x_u = users' factor 1 score, y_u = users' factor 2 score, z_u = users' factor 3 score.

It is reasonable to define the semantic distance (Table 8) as the degree of consistency in the product perception of designers and users; the shorter the distance, the more consistent these two groups.

The factor plot views (Fig. 5) indicated a big difference in the factor 1 axis (evaluation factor) between the two subject groups. Table 8 shows that the relative distance between designers and users for 8 out of 24 telephone samples is greater than 1.0. Among them, T5, T7, T8, T9, T16, and T21 are modern European styles and T15 and T17 are traditional styles.

Most of the modern telephone samples with a European style fall into the fourth quadrant in the designers' factor 1-factor 2 view, but into the lower central area in the users' factor 1-factor 2 plot. This indicates that the designers think that they are very creative and modern (factor 1) but negative in terms of compact and soft images (factor 2). The users, on the contrary, do not make such a sharp distinction between these images. These samples, therefore, scatter in the middle part of the users' factor plot diagram. This also happens with the factor 3 axis. The designers can clearly distinguish these samples in terms of the form, but the users are unclear about how to specify the telephone design. Thus, the

Table 7
Factors for the total subjects

Factors	Typical image words	Pct of Var (%)	Cum Pct (%)
Factor 1 evaluation factor	Creative, avant-garde, hi-tech, modern, futuristic, rebellious, mature, delicate	53.4	53.4
Factor 2 activity and shape factor	Compact, handy, soft, feminine	25.9	79.2
Factor 3 emotion factor	Emotional, particular	9.8	89.0

Table 8
The semantic distance between designers and users

	x_d	y_d	z_d	x_u	y_u	z_u	d_i
T1	− 0.555	1.299	− 0.485	− 0.454	0.740	− 0.831	0.665
T2	0.680	0.749	− 0.426	0.180	0.786	− 0.151	0.572
T3	− 1.464	− 1.719	− 0.966	− 1.383	− 1.227	− 1.173	0.540
T4	− 0.143	− 0.057	0.233	0.302	0.388	0.158	0.633
T5	2.156	− 1.870	1.611	1.066	− 1.003	0.761	1.632
T6	− 0.306	1.427	0.933	0.102	1.253	0.731	0.487
T7	− 1.235	0.777	− 1.307	− 0.870	0.398	− 0.017	1.393
T8	0.198	− 0.484	− 1.672	− 0.783	− 0.817	− 1.134	1.167
T9	2.023	− 1.600	− 0.628	1.001	− 0.794	0.127	1.504
T10	0.537	− 1.339	− 0.932	0.132	− 1.212	− 0.922	0.424
T11	− 1.177	1.060	0.314	− 0.420	1.019	0.247	0.760
T12	− 0.791	0.129	0.482	− 0.448	0.794	0.301	0.770
T13	− 0.934	− 0.766	− 1.627	− 0.256	− 0.832	− 0.931	0.974
T14	− 0.233	1.233	0.107	− 0.493	1.182	0.290	0.323
T15	− 2.125	− 0.263	1.667	− 0.732	− 0.164	2.193	1.492
T16	1.491	0.346	− 1.665	0.331	0.536	0.154	2.167
T17	− 2.084	− 2.285	2.073	− 0.949	− 1.887	1.806	1.232
T18	0.386	0.530	1.701	0.286	0.998	1.014	0.838
T19	1.166	0.384	0.601	1.019	1.191	0.513	0.825
T20	1.826	0.103	0.588	1.219	0.809	0.558	0.931
T21	1.280	0.111	0.262	0.211	0.084	− 0.429	1.273
T22	− 0.692	0.302	− 1.190	− 0.263	0.623	− 0.733	0.704
T23	1.191	− 1.037	− 0.199	0.397	− 0.917	− 0.364	0.820
T24	− 0.291	0.561	− 0.924	− 0.099	0.461	− 0.720	0.298

factor score range of the designers for factor 3 is much greater than that of the users.

As far as the traditional telephone samples are concerned, the two subject groups vary on the factor 1 axis. These samples fall on the left side of the third quadrant in the designers' view, but come closer to the central part in the users' view. This indicates that the designers have a very negative impression of Samples T15 and T17. On the other hand, the users' impression, although not positive, is not so extremely negative.

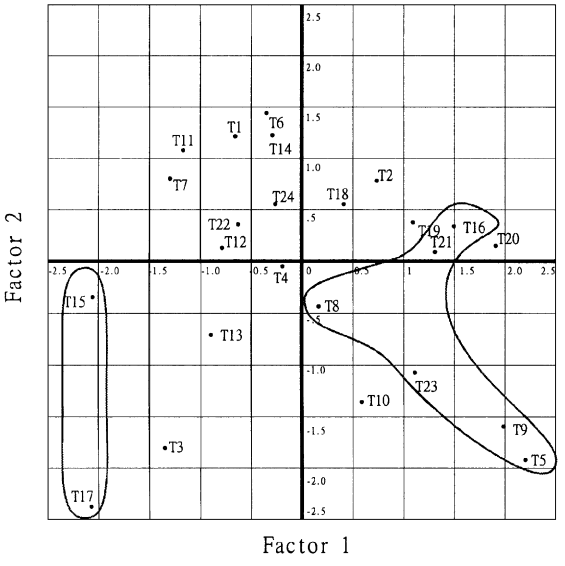
These factor charts visualize the semantic structure of the subject groups. Moreover, they help to explain that the difference between designers and users is primarily due to factor 1, the evaluation factor.

3.4. Building the design reference model

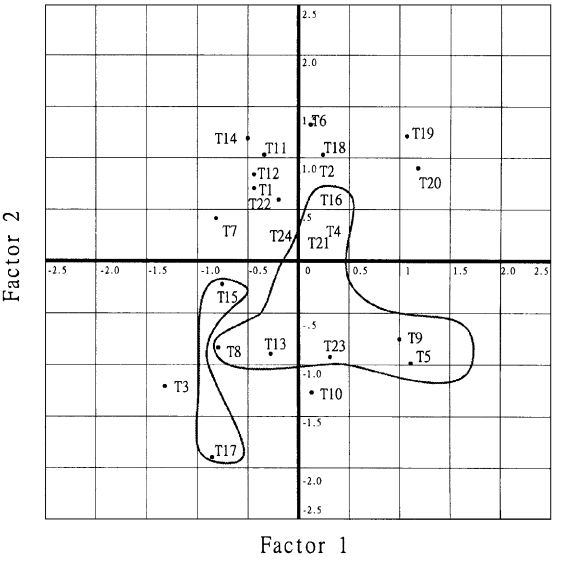
Users' image of a product is a complicated psychological phenomenon in that many factors will influence such a perceptual representation. With a telephone, both obvious and hidden elements will affect the users' image to a certain degree. Furthermore, differences between designers and users might exist due to a variety of agents. To investigate the relationship between users' perception and the treatment of product form, a conjoint analysis was performed. It provides a statistical procedure for identifying the relative weighting of each design factor and factor level in the perception of telephone design.

3.4.1. Morphological chart for the telephone samples

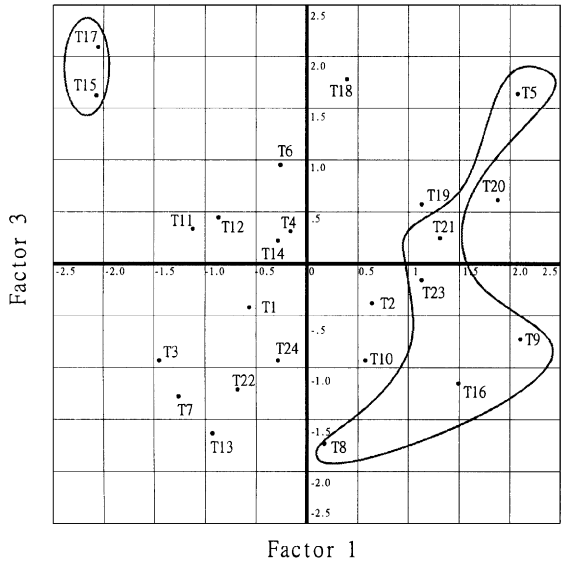
In the conjoint analysis, the dependent variable is the evaluation score for the preference of all subjects, and the independent ones are the indicated values of design factor level, an orthogonal design. The design factor level is obtained by morphological analysis. Two senior product designers clarified five telephone design factors, including the body, receiver, digital button, display, and function



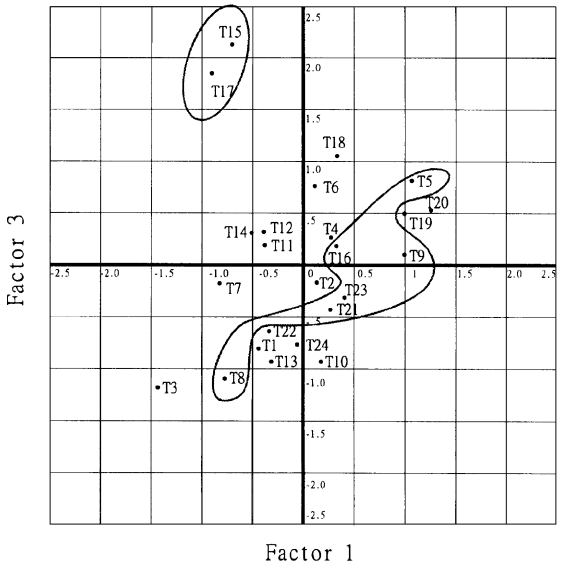
Factor 1-Factor 2 view of designers



Factor 1-Factor 2 view of users



Factor 1-Factor 3 view of designers



Factor 1-Factor 3 view of users

Fig. 5. Factor positions ofthedesignersandusers.

keys. Every design factor is then divided into several levels, as can be seen in Table 9.

3.4.2. The relative importance of design elements

The conjoint analysis tells us the relative importance of each design factor, that is, the extent to which it contributes to the preference evaluation. Table 10 shows the results for designers and users.

The results of Table 10 indicate that the ranking order of design factors in the designers' positive perception of real telephone samples is: display

Table 9
Design factor levels of telephone samples

Design factor	Levels of design factor			
A. Body	a1: Rectangular	a2: Solid	a3: Curvilinear	a4: Geometric
B. Receiver	b1: Curvilinear	b2: Old K-type	b3: Sharp geometric	b4: Rounded rectangular
C. Control buttons	c1: Rectangular	c2: Oval (elliptical)	c3: Organic	
D. Display	d1: Separated	d2: Integrated with fun keys	d3: Organic	d4: None
E. Function keys	e1: Rectangular	e2: Oval (elliptical)	e3: Running track circle	

Table 10
Averaged subfile for designers and users

Designers		Design factor levels	Users	
Importance	Utility (part-worths)		Utility (part-worths)	Importance
Body	− 0.686	a1: Rectangular	− 0.1681	Body
22.66%	− 0.189	a2: Solid	− 0.8073	24.46%
	1.2106	a3: Curvilinear	0.786	
	− 0.3356	a4: Geometric	0.1894	
Receiver	0.0577	b1: Curvilinear	− 0.0222	Receiver
23.47%	− 1.1055	b2: Old K-type	− 0.1944	17.56%
	1.0068	b3: Sharp geometric	0.2151	
	0.041	b4: Rounded rectangular	0.0015	
Digital buttons	− 0.0598	C1: Rectangular	− 0.3061	Digital buttons
12.09%	0.4411	C2: Elliptical	0.1386	14.28%
	− 0.3813	C3: Organic	0.1674	
Display	0.5613	d1: Separated	− 1.0738	Display
30.91%	− 1.4231	d2: Integrated	− 0.1482	24.53%
	1.0629	d3: Organic	1.0579	
	− 0.2011	d4: None	0.1641	
Function keys	0.096	e1: Rectangular	− 0.6896	Function keys
10.86%	0.0822	e2: Elliptical	0.4442	19.17%
	− 0.1783	e3: Running track circle	0.2455	

(30.91%), receiver (23.47%), body (22.66%), digital buttons (12.09%) and function keys (10.86%) ($R = 0.829$), whereas that of users is: display (24.53%), body (24.46%), function keys (19.17%), receiver (17.56%), and digital buttons (14.28%) ($R = 0.954$). The higher percentage here means the greater relative importance of the design item, the greater the positive influence it will have in the perception of the product.

For the designers, the display factor plays the most important role in positively affecting their perception; body and receiver factors are second, while function keys and digital buttons are third. For the users, display and body factors have the largest positive influence upon their evaluation; function keys and receiver are second; digital buttons are third. Thus the body, digital buttons and function keys are differently ranked. The responses of these two subject groups were similar with regard to the design items of display and receiver, in terms of their relative importance to their product perception. Finally, in terms of relative importance, more variation is shown in design factors for the designers than the users. This confirms the fact that designers are more sensitive and discriminating with regard to product form.

3.4.3. The utility (part worth) of design factor levels

As mentioned previously, different design elements may play different roles in affecting the subject's perception. In a conjoint analysis, each level of the design factor can be correlated with utility or part worth (Table 10). Fig. 6 shows the distribution patterns of designers and users in terms of design factor levels.

As far as the body is concerned, the curvilinear body is positive for both designers and users. Rectangular and solid bodies are negative for both groups. Geometric shapes are negative for designers but positive for users.

In terms of the receiver, designers and users both opt for utility, although the old K-type and sharply geometric shapes have a large impact on the designers' preferences.

There is a big difference with regard to digital buttons. The rectangular type is negative for the designers (− 0.0598), but not so negative as for the users (− 0.3061). The elliptical shape is positive for both groups but to varying degrees. Organic buttons have a negative effect on designers' preferences (− 0.3813) but a positive effect on the users' assessment (0.1674).

The display is the most important design factor for both designers and users. The separated type has a positive impact (0.5613) on designers' preferences but a negative one (− 1.0738) on users. The integrated display is negative for both groups, but especially for the designers (− 1.4231). The organic display has a major positive effect upon both designers' and users' perception.

Finally, there is also a big difference in assessments of the function keys. Designers do not much consider the rectangular type (0.096) but users judge them negatively (− 0.6896). Elliptical function keys have a positive effect both on both designers and users. The running track circle style is negative for the designers (− 0.1783) but positive for the users (0.2455).

Generally, the designers can clearly distinguish the design factor levels. This is reflected by a greater range of perception, as measured by utility or part-worth values, for design factor levels. On the contrary, for the users, the range of utility values for

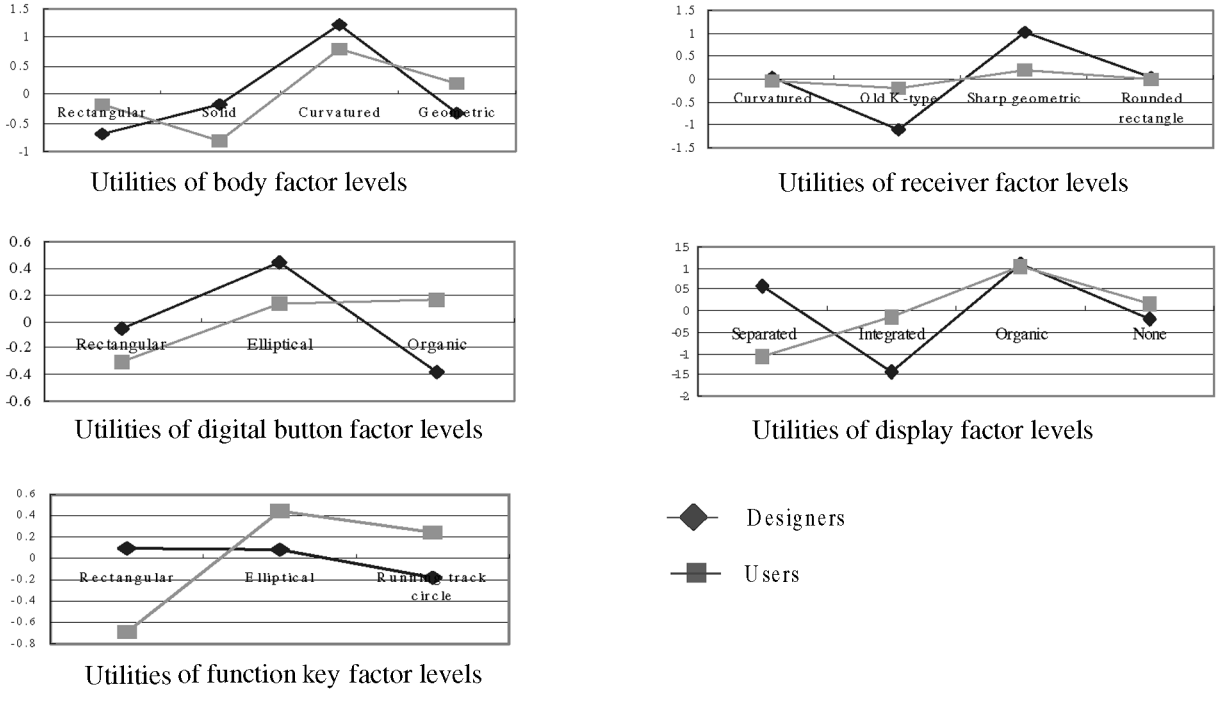


Fig. 6. The utilities of design factor levels for designers and users.

design factor levels is not wide. The designers' increased degree of variation regarding design factors is evident in Fig. 6, where we see that the users' level of variation is comparatively less. For example, the variation in the designers' perception of the receiver is much greater than that in the users' perception. Similar conditions can also be seen with digital buttons.

The utility of the design factor level shows us its relative importance in positively influencing the subject's evaluation. Thus if we want to develop a new telephone model, we can know that design factor levels [a3, b3, c2, d3, e1] will tend to be chosen by designers, and levels [a3, b3, c3, d3, e2] by users, because of their positive weights (Table 10).

From this diagram, one can extract the design factor levels important to both subject groups. The design factor levels with a positive value (utility) for both groups will be strongly recommended to designers who want to create a specific product image, while those with negative value (utility) for both groups should be avoided in telephone design. Energy and resources should be invested in design elements so as to best represent the values of the target population.

3.4.4. The design reference model

To predict the evaluation score for such combinations, one can apply the formula for an evaluation score from the conjoint analysis. For designers, the formula for predicted preference in telephone design could be expressed as

$$\tilde{Y}_{\mathrm{d}} = 4.3816 + WA\cdot AT + WB\cdot BT + WC\cdot CT + WD\cdot DT + WE\cdot ET, \qquad (5)$$

where $\tilde{Y}_{\mathrm{d}}$represents the predicted preference score of designers;

$WA = [-0.686\ \ -0.189\ 1.211\ \ -0.336]$;
$WB = [0.058\ \ -1.106\ 1.007\ 0.041]$;
$WC = [-0.06\ 0.441\ \ -0.381]$;
$WD = [0.561\ \ -1.423\ 1.063\ \ -0.201]$;
$WE = [0.096\ 0.082\ \ -0.178]$;
AT is the transpose of matrix A [a1 a2 a3 a4];
BT is the transpose of matrix B [b1 b2 b3 b4];
CT is the transpose of matrix C [c1 c2 c3];
DT is the transpose of matrix D [d1 d2 d3 d4];
ET is the transpose of matrix E [e1 e2 e3].

All design factor levels are equal to 0 or 1; for each design factor, there is one and only one whose value is 1.

On the other hand, the users' formula for predicted preference can be expressed as

$$\tilde{Y}_{\mathrm{u}} = 4.356 + WA\cdot AT + WB\cdot BT + WC\cdot CT + WD\cdot DT + WE\cdot ET \qquad (6)$$

where $\tilde{Y}_{\mathrm{u}}$ represents the predicted preference score of users;

$WA = [-0.168\ \ -0.807\ 0.786\ 0.189]$;
$WB = [-0.022\ \ -0.194\ 0.215\ 0.002]$;
$WC = [-0.306\ 0.139\ 0.167]$;
$WD = [-1.074\ \ -0.148\ 1.058\ 0.164]$;
$WE = [-0.690\ 0.444\ 0.246]$.
AT, BT, CT, DT, ET are the same as those in Formula (5).

Assign 1 to the selected design factor levels and 0 to the rejected ones in these formulas for the designers and users. One can get the predicted scores of 8.20 for the designers' best choice [a3, b3, c2, d3, e1] and 7.03 for the users' best choice [a3, b3, c3, d3, e2]. However, both scores fall into the very positive image range in only one situation. If one picks the users' favored items [a3, b3, c3, d3, e2] and applies this combination to Formula (5), a predicted score of 7.36 will be obtained for the designers. Similarly, if one picks the designers' favorite items [a3, b3, c2, d3, e1] and applies this series to Formula (6), a predicted score of 5.86 will be obtained for the users.

For alternative designer and user factor levels, these formulas can be applied to estimate the evaluation score, which can then indicate the direction of development of product design. Obviously, an optimal choice that meets the requirements of both designers and users might be found. Through a linear equation we can get the predicted scores of the total 576 solutions ($4\times4\times3\times4\times3 = 576$) for the two subject groups. The results reveal that the predicted scores of only two solutions, [a3, b3, c2, d3, e2] and [a3, b3, c3, d3, e2], meet the preference requirement (>7.0). The design factor level options

Table 11
The design factor levels options and predicted scores for preference

Design solutions	Design factor levels	Designers' score	Users' score
[a3, b3, c2, d3, e2]	a3 Curvilinear body b3 Sharp geometric receiver c2 Elliptical digital buttons d3 Organic display e2 Elliptical function keys	8.19	7.00
[a3, b3, c3, d3, e2]	a3 Curvilinear body b3 Sharp geometric receiver c3 Organic digital buttons d3 Organic display e2 Elliptical function keys	7.36	7.03

and their predicted scores are listed in Table 11. To arrive at a telephone design that meets both groups' preference requirements, the design factor levels [a3, b3, c2, d3, e2] and [a3, b3, c3, d3, e2] are the best choices.

4. Conclusions

The purpose of this study is to explore the differences between designers and users in their perception of product form. Designers and users were asked to utilize a semantic differential scale to rate their perceptions toward 24 real telephone samples. Several multivariate analyses were performed to analyze the subjects' perceptions and to build conceptual models that could act as guidelines for later product design and development.

The results show that some significant differences exist between designers and users in product form perception. On the one hand, the same product form will give designers and users different impressions. On the other, the same evaluative term or image-word might have different meanings for designers and users. The users are unclear regarding the precise sense of image-words such as "feminine," "avant-garde," and "emotional". The views of designers and users are thus significantly different regarding the telephone samples as well as the interpretation of evaluation adjectives. That is, to really explain why designers might value an "elegant" artistic style more than users, we must see that the conceptual models of these two subject groups are made up of different components. The "creative," "mature" and "delicate" telephone design images all play an important role in affecting the designers' preference, while the users' preference is affected mainly by the "delicate" image. The different relationships between image-word and design elements for the two subject groups, that is, their different conceptual models, cause the discrepancy in preference.

The reduction of this discrepancy is a challenge for the designers. One way to narrow the gap between the designers' and the users' conceptual models is to adopt a user-centered approach. Designers need to identify the characteristics of the end user, and study the users' needs and preferences as well as the latest design trends. This study provides a quantitative database of some important semantic features regarding product form. The optimal design factor levels obtained from the design reference model can serve as the basis for product design. Alternative styling solutions that integrate the features of these options can be developed in later phases of conceptual design and design embodiment. In this way, users' preferences and needs can be transmitted into design specifications and we can be sure that the design idea will meet the requirements of the end users.

To get a reliable marketing database of the users' needs and preferences, it will be necessary to conduct a larger-scaled subjective evaluation in the future. Efforts should be made to refine the system

so that it provides a better match with the more concrete affective responses of the end user. The image profile could be obtained through systematically manipulating the design elements in order to ascertain the target users' precise perception. In the future, of course, new designs and new technologies will also be introduced. Finally, the results of such a study conducted in Taiwan may be limited to the Chinese culture. Cross-cultural studies will therefore be required in order to arrive at more culturally generalized conceptual models and potentially successful product designs.

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