Investigating Design Style Evaluation in User Cognitions Using Statistical Methods

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Abstract. Based on the modern design theory, the product design style is the subjective feeling of the product's whole form, and its research and classification depend on the user's sensibility evaluation. But for a long time, the emphasis of style quantification has focused on the relationship between user evaluation and design form elements, but seldom consider the influence of user cognition on perceptual evaluation, so it limits the validity and scope of application of such correlation model. Therefore, based on the research approach of cognitive theory, this paper puts forward the hypothesis and the influence of association and Recognition cognitive process on the evaluation of product design style, and takes a group of modernist products as an example to carry on the empirical research. Based on the research approach of cognitive theory, this paper uses statistical methods, puts forward hypotheses, and conducts empirical research on the impact of cognitive processes such as association and recognition on product design style evaluation, taking machine aesthetic design style as an example. The results show that Lenovo has a great influence on the style evaluation of products, and its influence comes from the expressive dimension of design style; There is no significant correlation between recognition and product design style evaluation, but only has a weak impact on some single observation variables. In addition, the results of exploratory factor analysis (EFA) on the experimental scale show that there are two potential evaluation dimensions when users evaluate the machine aesthetic style.

Keywords: Product design · User cognition · Statistical methods · Design style evaluation

1 Introduction

Design style research is an important field in industrial design. Style is an indispensable attribute of the design [1]. In previous style studies, the product style was often defined from the perspective of the designer, such as the period of design, the nationality of the designer and the cultural ownership, and the similarity in the geometric features of the product is used for the classification study [2]. Modern design theory is more inclined to study from the perspective of the user, and regards the design style as the user's overall perceptual knowledge of product features, namely the product image [3],

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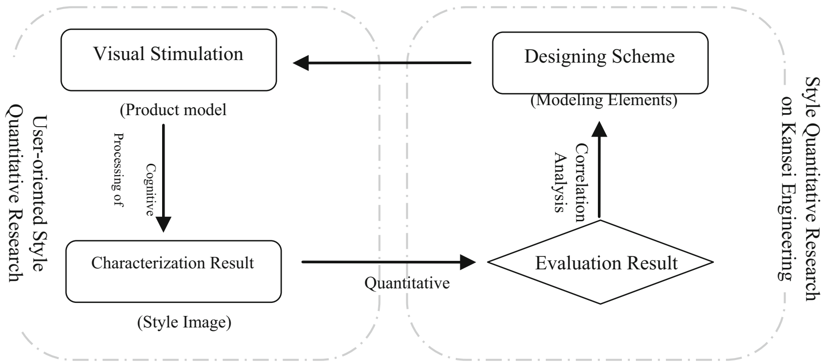

Fig. 1. Two Styles of Quantitative Research Framework and their Relationships

and some literatures [4] also name it as style image. The image of the product can be regarded as the representation of the design style in the user's psychology. It is an important way for the user to obtain the aesthetic experience [5] and conduct brand recognition [6] from product design. At the same time, the successful classification of styles in the aesthetic dimension can provide a self-rewarding cognitive experience [7, 8], which can enhance the user experience. In previous studies, the user's perceptual evaluation was often quantified through psychological semantic difference scale, and a more mature research system called Kansei Engineering was formed. It is widely used in industrial design [9]. Kansei Engineering research focuses on the relationship between user evaluation and design modeling elements, but seldom considers the impact of user perception on perceptual evaluation, thus limiting the effectiveness and application of such association models. Therefore, this paper intends to adopt a user perception-oriented style qualitative study. The research framework is shown in Fig. 1.

2 Approach

2.1 Subjects

Previous studies have shown that professional knowledge affects people's emotional evaluation of products [10]. Therefore, this study randomly selected 100 non-design professionals from Chengdu ordinary citizens as subjects and obtained 72 valid questionnaires. The questionnaire collection rate was 72%, of which the subjects were aged from 16 to 70 years old, including 38 males and 34 females, with an average age of $M = 41.43M = 41.43$ and an age difference of $M = 17.1$.

2.2 Experimental Materials

This article takes the Machine Aesthetics design style as an example. Machine Aesthetic style rises from the beginning of the 20th century, which emphasizes the expression of industrialization or modernity and is one of the major design styles in industrial design. According to works of British scholars Reyner Banham [11] and Penny Sparke [12],

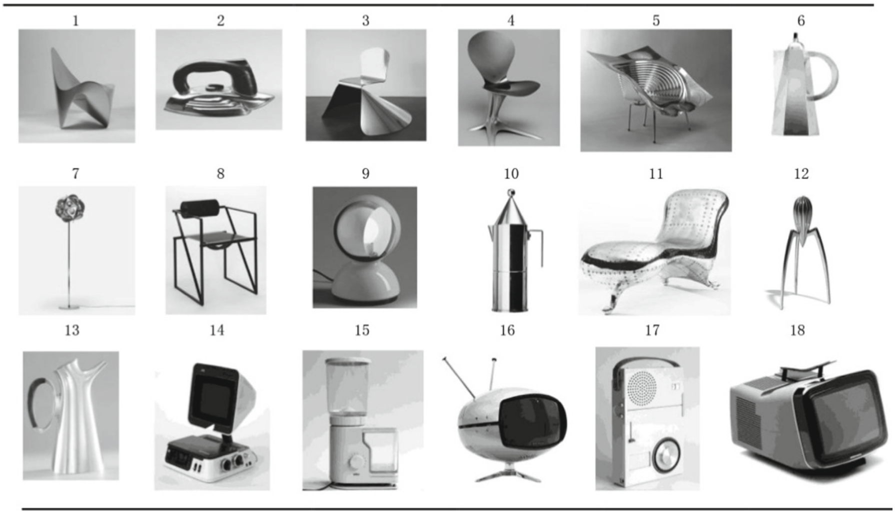

Fig. 2. Product Samples and Numbering

the representatives of this style include works by many famous designers such as Dieter Rams and Aldo Rossi, covering a wide range of design styles. This study selected 18 representative design products as shown in Fig. 2. The average of the evaluation values of each of the 18 tested products was taken as the evaluation value of the subject for this style type. All products appear in the questionnaire are black and white pictures, and are arranged in the same position in the same size of the questionnaire to reduce the influence of differences in color, material, size and position. Meanwhile, when materials are provided to the subjects, the products sequences are random which are generated by software, so as to avoid the influence of the order. Different from Fig. 2, the subjects were provided no relevant information to the products in addition to product pictures and question descriptions when they obtained experimental materials.

2.3 Questionnaire Establishment

Since the study focuses on products of specific styles, there was no available ready-to-use scale, so questionnaires and scales were prepared based on the experimental research framework. Generally, style quantitative research adopts semantic difference method, but it is easy to produce ambiguities using only a pair of adjectives to describe the observation variable. Therefore, in this study, Lee's 10-level scale was used to describe the evaluation variable through a sentence. For example, with regard to the technical sense of the product, the questionnaire describes this: What do you think of the technical content of this product? (1 = very outdated, 10 = very advanced).

With regard to the research object of machine aesthetic style, this study will use the overall impression of the user as a latent variable of the evaluation scale. And through a comprehensive study of the literature on the previous design theories[11–15], a general description of perceptual semantics involving this category was given. The 12 evaluation indicators were selected as observation variables, which includes product typicality, distance perception, speed perception, strength sense, volume sense, organic sense, technicality, future sense, novelty, functionality, price prediction, and purchase attractiveness.

The questionnaire consists of two parts. The first part is a multiple-choice question, which is used to observe the subject's identification and association of the products. Each participant was asked to observe all 18 products, and then in the identification questions, the subjects were asked to select the correct category of products from multiple options and to count the number of correct identifications. In the association questions, the subjects were asked to report their associated objects, and to count the number of associations produced by the subjects. The second part of the questionnaire is the perceptual evaluation scale for the image of Machine Aesthetic. The scale contains 12 evaluation items, and the scores are 10 grades. The internal consistency reliability of the scale is $\alpha = 0.886$. After removing two unsuitable ones, the internal consistency reliability was improved to $\alpha = 0.934$. Therefore, the final scale contains a total of 10 evaluation items, which are the product's speed, strength, volume, organic, technicality, future, novelty, function, price forecast and purchase attractiveness. The test-retest reliability of each item is $r = 0.524$, the structural validity KMO is 0.857, and the Bartlett spherical test statistic is 483.072, $p < 0.001$.

After determining the reliability and validity of the total scale, the exploratory factor analysis (EFA) method was used to analyze the potential factors contained in the scale to determine the dimensions of the scale. Statistical analysis software spss19.0 was used to perform principal component analysis on the 10 evaluation items (variables) of the scale through varimax rotation. The results of the analysis shows that there are two influencing factors among the ten variables. According to the load of the factors that form each variable, this study divides the scale into two dimensions and is named as the performance dimension and value dimension. The subscales of the performance dimension include five observational variables: speed sense, strength sense, volume sense, organic sense, and future sense. The internal consistency coefficient $\alpha = 0.912$, the KMO of structural validity is 0.848, and Bartlett spherical test statistic is 260.342, $p < 0.001$. The subscale of the value dimension contains five observational variables including technicality, novelty, functionality, price forecasting and purchasing attractiveness. The internal consistency coefficient $\alpha = 0.844$, the KMO of structural validity is 0.774, and Bartlett spherical test statistic is 145.272, $p < 0.001$.

2.4 Statistical Approach

The main purpose of the study is to observe whether the subject's identification and association of the product will affect the overall evaluation of the subjects on specific design style. Through the questionnaire test, we collected the number of correct identifications of 18 products and the number of reported associations, and grouped the subjects according to the judgment results. The test results were used to compare the product evaluation results between different groups.

Due to the complexity of the questionnaire preparation and the long time to complete, it can only obtain a small number size of the subject samples. The sample data does not follow the normal distribution after grouping. Therefore, it is regarded as free distribution using non-parametric statistical methods, and Spearman is used in related analysis.

Kruskal-Wallis test is used for multiple independent samples in inferential statistical analysis.

3 Results

3.1 Descriptive Statistics

The first part of the questionnaire, that is, each participant's association with 18 products and the number of successes of recognition was counted. Then based on the second part of the questionnaire, the evaluation data collected by the scale, the average of the 18 evaluation results made by each subject on the 18 products was used as the final evaluation result to offset the situational differences brought about by different products during the overall evaluation of the style type. The final two parts of the survey results are summarized in Table 1. The results will serve as the basis for subsequent correlation analysis and inferential statistical analysis.

The results of the Spearman correlation analysis between the number of associations and recognition accuracy and the user's evaluation indicators and the two potential factors are shown in Table 2.

From this table, we can see that there is a significant moderate positive correlation ($r_s = 0.343$, $p < 0.01$) between the associative behavior and the performance factors of the style, and there is a significant positive correlation ($r_s = 0.639$, $p < 0.01$) between the two evaluation dimensions.

3.2 Test Assumption

Based on the previous correlation analysis, we can know the evaluation of association behavior on the aesthetic design style of the machine, especially the influence of the

Table 1. Cognitive Behavior Observation and Style Evaluation (n = 72)

	M	(SD)			
Association (counts)	19.61	9.20			
Recognition (counts)	13.00	2.57			
	M	(SD)			
Total Points	4.44	0.91			
	M	(SD)		M	(SD)
Efficiency Performance	4.94	0.99	Style Performance	3.95	1.00
Novelty	4.93	1.25	Organic	3.26	1.27
Technology	4.90	1.18	Speed	3.27	1.54
Function	5.49	1.05	Strength	4.37	1.21
Price	5.05	0.93	Volume	4.73	0.93
Purchase	4.33	1.35	Future	4.09	1.43

Table 2. Correlation coefficients of explanatory variables and associations and recognition ($n = 72$)

	Association	Recognition	Style Value	Style Performance	Total Points
Association	–	.092	.229	.408**	.343**
Recognition		–	.017	– .035	.008
Efficiency Performance			–	.639**	.903**
Style Performance				–	.897
M	19.61	13.00	4.94	3.95	4.44
SD	9.20	2.57	0.99	1.00	0.91

Notes: *$p < 0.05$ **$p < 0.01$

performance evaluation dimension. Combining the hypothesis of the cognitive behavioral impact evaluation results originally proposed in the article, ranking according to the number of associations reported in the experiment, the subjects were equally divided into three groups with 24 individuals in each group, representing different association activities. The rank sum test between groups was performed. The test results are shown in Table 3. For evaluation of product style effectiveness, test statistics $H_{obt} = 10.397$, $p < 0.01$, and evaluation of product style performance, test statistics $H_{obt} = 7.02$, $p < 0.01$. This result shows that, at the significant level of $\alpha = 0.01$, there are significant differences in the evaluation of the two dimensions of product design style between different test groups in the degree of association activity.

Table 3. Impact of Association on Style Evaluation

	Low Activity ($n = 24$)	Moderate Activity and Low Activity ($n = 24$)	High Activity and Low Activity. ($n = 24$)			
	R_1	R_2	R_3	H_{obt}	d_f	p
Total Points	25.10	40.29	44.10	11.07	2	0.004
Style Value	25.65	44.46	39.40	10.39	2	0.006
Novelty	26.98	43.04	39.48	7.80	2	0.020
Technology	28.50	45.40	35.60	7.89	2	0.019
Function	28.29	43.46	37.75	6.44	2	0.040
Price	26.50	43.13	39.88	8.52	2	0.014
Purchase	25.33	40.69	43.48	10.47	2	0.005

(*continued*)

Table 3. (*continued*)

	Low Activity (n = 24)	Moderate Activity and Low Activity (n = 24)	High Activity and Low Activity. (n = 24)			
Style Performance	26.46	34.60	48.44	13.53	2	0.001
Organic	31.96	32.27	45.27	6.33	2	0.042
Speed	29.48	35.19	44.83	6.60	2	0.037
Strength	26.90	37.46	45.15	9.21	2	0.010
Volume	32.15	37.50	39.85	1.71	2	0.425
Future	27.17	34.63	47.71	11.86	2	0.003

4 Conclusions and Discussion

The study found that there are two potential dimensions in the evaluation of the style of machine aesthetic design, and they are related to each other. Therefore, it is likely that there is a second-order structure among the observed variables involved in the scale, which provides a direction and basis for further confirmatory factor analysis and structural equation modeling.

The results of the study show that the assumptions proposed at the beginning of the article are partially established, that is, for the two cognitive behaviors, association and recognition behavior, of which only one has an impact on the evaluation of product intentions, and it only has a significant effect on the performance dimension of the style. And the experiment could not detect the effect of the identification behavior on product evaluation. The reason for this result may come from two aspects. First, the user's performance evaluation of the design style is likely to be an implicit attitude evaluation, so it may be closer with the association processing. Secondly, according to the association-proposition model [16], recognition is also a kind of propositional behavior, for results of recognition judgement itself may be true or false. Propositional behavior may have an impact on the evaluation of style's efficiency, while experiments have not detected this effect. That may attributes to the fact that the observation index of the recognition behavior is the number of times that the classification of a group of products is correctly identified. It is essentially the statistics of the recognition success rate. It is the observation of the behavior result rather than the behavior itself, while the observation of the association behavior is an observation of the degree of activity.

This study is a user cognition-oriented attempt to quantify style evaluation. According to the nature of association processing [17], we can infer that the formation of representation of style images in user's cognition maybe related to the information activated from the memory of the user's cognitive system by the visual stimulus of the product image. The difference from the previous quantitative research of style is that, instead of conducting classified study based on characteristics of the product, this one is the study of the formation mechanism of style image in the user's cognition, that is, the style evaluation itself is regarded as a psychological factor for quantitative research.

This path can better combine design research with cultural or group studies. Different populations or cultural backgrounds need different interpretations for consistency and differentiation of appearance elements, and differences in different cognitive behaviors will provide the basis for these different interpretation paths.

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