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Use Aesthetic Measure to Analyze the Consumer Preference Model of Product Forms

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Abstract*— As technology development advance rapidly, for customers the essential physical function of a product is no longer the decisive factor the attracts them to buy. Further-more, customers begin to pursue the products in personality. Customers have a fixed preference model for the product form, if which can be analyzed, designers are able to figure out quickly whether the form designs satisfy the target groups or not. In the study, the product form is selected as the major target for investigation of consumer preferences with variety vases. First, screen out the aesthetic principles, composed of symmetry, minimalist, and cohesion, the different values of which, by calculating objective quantization on the evaluation model of aesthetic measures, can serve as different attributes and levels, further combined with consumer preferences for a conjoint analysis to determine the aesthetic values. Based on the two indices in the conjoint analysis, it has been verified the subjects indeed possess an established preference model. Followed by the finding, the concept of market segmentation was utilized to divide the subjects into six groups by the differences in the part-worth utilities perceived. The figure of the form preference models, constructed by the result, can be detected with the reverse engineering in different groups' preference values. The approach can also be applied to design or adjust the form design with the correct direction. Finally, select a vase with an ordinary preference to a group and modify the details in order to cater more a target group in the direction of the aesthetic values preference results.

Index Terms—**product form, aesthetic measure, consumer preference, preference model, conjoint analysis.**

I. INTRODUCTION

According to the Hierarchy Theory of Human Beings from psychologist Maslow [1], it reveals that after reaching the essential physiological, safety, and social needs, people will then turn to even higher hierarchical level to pursue self-demands and the ambit of self-actualization. When a product reaches maturity, customers will consider the product that satisfies both their basic essentials and outstanding personality, which has been an important way to maintain market share [2]. Though, the product differentiation becomes a design trend nowadays [3][4]. The study assumes that customers have a fixed preference model for the product form. Based on collection and analysis of large amounts of data, it can realize the preferences in each group [5]and it is possible to raise the product sales as well [6]. Using the discussed results, group the subjects in same taste together to achieve demassification. Then in application, by form preference model, the aesthetic values of each group can be examined through which designers can know how to modify the form to satisfy the group.

II. RELATED WORK

The feeling of product bases on the cognition of form that is composed of modeling, color, and texture. Form affects a product styles most [7][8][9]. The types of visual processing of human can be analyzed by two stages: first, a rapid scan of whole vision image; second, a vision processing model involving paying attention to details [10]. The different form constructions such as symmetry, types, and the position, regularity, and amounts of elements, etc. They are linked closely with the final perception [11]. The centroid of the whole object and the centroid, volume, distance, side length, and angles of each element directly influence the form aesthetic measure and b able to make up of the form aesthetic models [12].The different forms make the different feelings on human cognition, so the discussion of consumers' cognition of the forms is often conducted by image vocabularies depending on Kansei Engineering, a technique that translates human imaginary and emotional expectations for a product into physical design elements for concrete development and design. Then the emotional measures and physical quantities that cause emotional stimuli to happen can be found. They serve as the foundation of design development [13]. The approach is usually conducted with the computer technology and statistical analyses for the design models developed by mental and physical needs of human in the products. In the method, it is often assisted by the semantic differential scale, morphological analysis, Likert scale, and so on [14] to construct a computer aided design (CAD) system to generate product forms intended by consumers. The study applies Multidimensional Scale (MDS) which is proposed by Torgerson in 1954 to assort huge amounts of data and choose one as representative from each group. According to Conjoint Analysis developed by Luce and Tukey in 1964, then the values of a level between 0 to 1 as aesthetic measures weigh the preferences of consumers; to determine whether the subjects possess the contemplated preference models for the preferred forms, the two indices of Pearson's R and Kendall's tau can be utilized as the assessment basis. Essentially, use cluster analyses classify observations and variables into each group to get the quantitative value of preferences from the groups. In addition, Myszkowski and Storme performed several Visual Aesthetic Sensitivity Test (VAST) [15] to explore the visual aesthetics on 2D images and also seek for numerical approaches to aesthetic problems. Furthermore, Hermes et al. also attempts to apply the idea of aesthetic measurement in the area of landscape design [16] and the

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quantitative results demonstrate the beneficial approach in decision-making process.

III. METHODS

A. Collection of the Samples

Figure 1 illustrates the research process of this study. The subject samples are selected on a fixed range of ages and occupations. The study targets at college students and postgraduates. For the genders and with/without design backgrounds, the two class variables consider as equal distribution when searching for subjects to ensure that samples are provided with a certain degree of diversity. The expected number of subject samples is above one hundred.

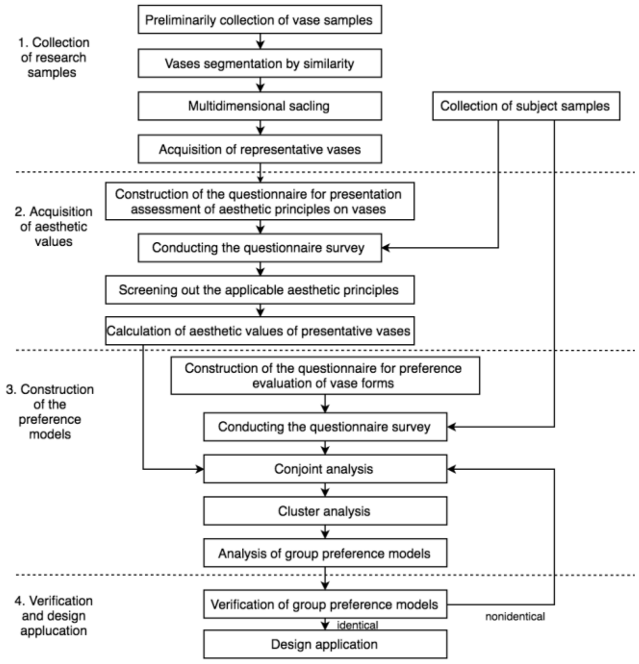

Fig 1 Flowchart of the Research Process

Vases are the target samples for form investigation. First, collect lots of vase photos without strong concrete image, overly patterned design, and functional presentations which make forms as the only factor for evaluation. All the vase samples have been processed as indexed cards in grey scale. Then by using the method of metric MDS to generate the perceptual map, presenting the similarity distances between products with a visual perceivable way, the vase samples with a high degree of homogeneity are assorted into the same group, where one sample is selected to represent each evaluation group by the 16 experts that have had design experience for over 4 years. Finally, building 3D models without flowers, material defined, shadow, color, and patterns in the same environment further ensure the form and eliminate other influential factors that make the measured results more precise. Meanwhile, from the function of "Mass Properties" and "Measure Tool" in the SolidWorks, the physical parameters, the centroid of object, the centroid of elements, volume, distance, length, width, height, angle, and so on, can all be acquired for the next step, the aesthetic measure evaluation.

B. Collection of the Samples

This step will be carried out by the questionnaire investigation. The questionnaire is composed of three options: "possess the feeling of said aesthetic principle", "doesn't possess the feeling of said aesthetic principle", and "unperceivable". The operators will explain the complete meaning of all aesthetic principles to ensure the subjects fully understand the assessments before conducting the survey. In addition, for consistency on cognition, the structure of the questionnaire is designed to evaluate an aesthetic principle of all the vase samples at one time, the schematic shown in Figure 2.

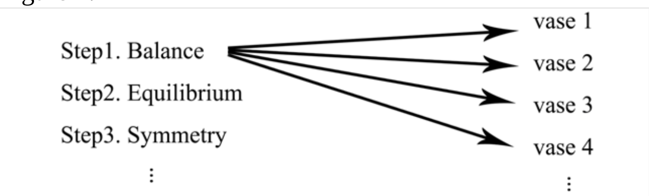

Fig 2 Questionnaire Structure of Applicable Principles Screening

The results are the dispersion degree of subject average answers from statistically investigated. If a question gets a certain answer, the dispersion degree will be large, representing that subjects have a greater consistency on the perception for the aesthetic principles, and answer consistency is better. On the other hand, if a statistical result is scattered, small dispersion value, it means the opinions are diverged. Additionally, if "unperceivable" option is selected by more than a quarter of the subjects, it indicates the aesthetic principle has high vagueness to the vase samples and more than a quarter of representative samples are high vagueness in a certain aesthetic principle. The certain aesthetic principle will be eliminated in the study.

C. Construction of the Preference Models

First, ask the subjects to pick up the most favorite vase at the first view from all samples, then to pick up the most disliked one from the remaining of samples, and the last, to sequence the rest of the vases from favorite to disliked, shown in Figure 3. After acquisition the quantized values of aesthetic principles and the ranking of subject preferences for vases, the SPSS syntax of conjoint analysis has been utilized for exporting the part-worth utilities of each subject toward each aesthetic values. The part- worth utilities represents the degree of influence of aesthetic principles in different values on subjects' preference ranking, i.e., the preference weights of each aesthetic values on each subject. As following, the subjects in close tastes segment the markets based on the similarity of part-worth utilities for each aesthetic values. The segmentation process has been conducted by the cluster analysis, and the part-worth utilities sequences of each subject in each aesthetic value can serve as segmentation inputs, and the cluster analysis can conduct the segmentation based on the similarity of sequences.

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After the segmentation, the part-worth utilities of subjects within an identical cluster for each aesthetic principle can be averaged as a single utility by means of arithmetic averages. This utility is namely representative part-worth utility of each group on the aesthetic values. Moreover, the two indexes of Pearson's R and Kendall's tau in the conjoint analysis will be detected to prove whether the assumed preference models of forms exist or not. If the two indexes indeed reach the standard, the f preference models can be constructed. Different aesthetic principle values can serve as the x axis, and the average of each group's part-worth utilities can serve as the y axis. In addition, the original Kano model [17] has been modified in the way of adding the reversal thinking to the Attractive Quality and must-be Quality, as shown in Figure 4. Which will be used to analyze the preference models.

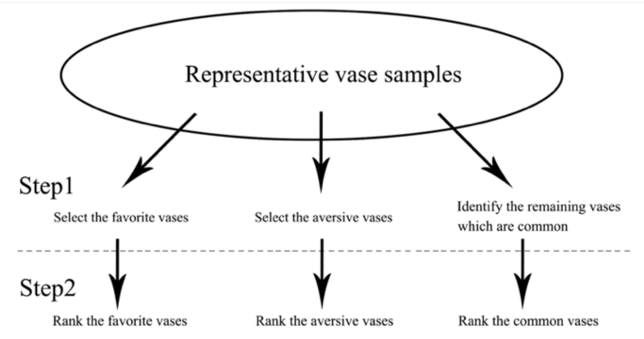

Fig 3 Questionnaire Structure of Preferences

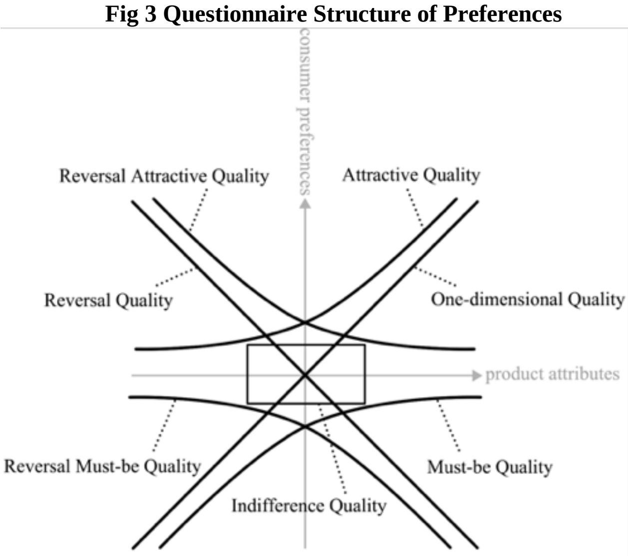

Fig 4 Modified Kano Model

D. Verification and Design Application

Based on the figures of preference models of each aesthetic group, preference degree of vases can be determined in comparison with the part-worth utilities of its aesthetic values, and the part-worth utilities can further be summed up to obtain the overall preference of vase forms for each group. The reversed engineering can assist inspecting the designed vases whether reach the target or how to improve.

The verification is to randomly inputs both three representative samples and the three of the remaining samples into the model that are simultaneously assigned the subjects of different aesthetic groups again to rate the preference. Further, are the predicted preference ranking calculated by the part-worth utilities and the actual ranking results matching? If they are identical, then it is able to apply the results into design process; if not, reconstruct the preference models; According to the inspection, the physical parameters adjustments based on the equations of evaluation model that affect each aesthetic principle are shown in Table 1.

Table 1 Physical Parameters Affecting Each Aesthetic Principle

Rhythm	Element volume	Centroid position		
Cohesion	Object dimension	Element dimension		
Minimalist	Element class	Element quantity		
Unity	Element class	Element quantity	Element volume	Object volume
Proportion	Object dimension	Element dimension		
Symmetry	Object dimension	Centroid angle	Centroid position	Centroid distance
Equilibrium	Object dimension	Centroid distance		
Balance	Element Volume	Centroid distance		

IV. RESULTS

A. Collection of the Research Samples

For a pre-specified range of age and occupation, there are 107 subjects, who are students in colleges or graduate schools and are classified by two class variables, male or female and design or non-design background, to establish the diversity. The subject composition is shown in Table 2.

Table 2 Structure of Subject Samples

	Design background	Non-design background	Total
Male	25	26	51
Female	29	27	56
Total	54	53	107

Regarding the vases, the study collects 100 sample images, which contain diversified featured forms of vases, and they are respectively numbered as 0~99. The dissimilarity matrix, obtained previously, is entered into the statistical software SPSS for the analysis of metric MDS and the perceptual map. Assume that the value of the stress convergence is 0.001, the

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minimum stress is 0.005, and the times of maximum iterations is 30 and analyze it from two to six dimensions respectively. The study adopts the two-dimensional results: the stress value is 0.12863; RSQ is 0.94036, within the acceptable range; then put the actual forms on the perceptual map, shown in Figure 5, where there are 21 groups. Figure 6 shows the representative samples in each group, selected by experts.

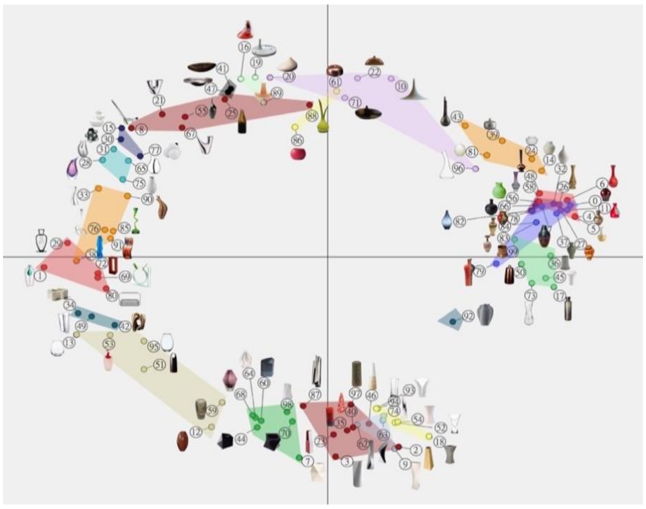

Fig 5 The Vase Sample Groups on the Perceptual Map

Fig 6 21 Representative Vase Samples

B. Acquisition of Aesthetic Values

Ask 60 people randomly selected from the subjects to conduct the survey for presentation assessment of aesthetic principles on vases, and based on the results, the aesthetic principles suitable for the study include Equilibrium, Symmetry, Minimalist, and Cohesion. The physical parameters of vase samples for the calculation of each aesthetic principle can be obtained by the functions of "Mass Properties" and "Measure Tool" in SolidWorks. These parameters can be substituted into the equations of aesthetic principles in the evaluation model of aesthetic measures, and the objective measures of Equilibrium, Symmetry, Minimalist, and Cohesion can be obtained. From the calculation results, the values of the representative vases in the principle of Equilibrium are either 0.9 or 1. Thus, the principle of Equilibrium may be less identifiable for vases on the rational assessment and meaningless for the preference analysis afterward. Thus the aesthetic principle of Equilibrium is discarded. The study adopts Symmetry, Minimalist, and Cohesion essentially in the follow-up research.

C. Construction of the Preference Model

According to the sequence similarity, the part-worth utilities of 107 subjects toward the aesthetic values, are segmented by the hierarchical cluster analysis. The cluster method that has been utilized is the Within-groups linkage measured by the method of Euclidean distance, the output tree diagram as shown in Figure 7. To ensure that the construction of preference models can make the prediction results even more precise, the subjects are divided into the same group only if whose homogeneity reaches the certain criteria (as the dash line in Figure 7) in the cluster analysis.

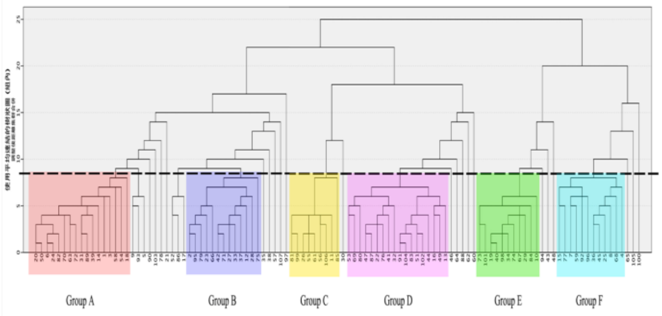

Fig 7 Tree Diagram of Cluster Analysis

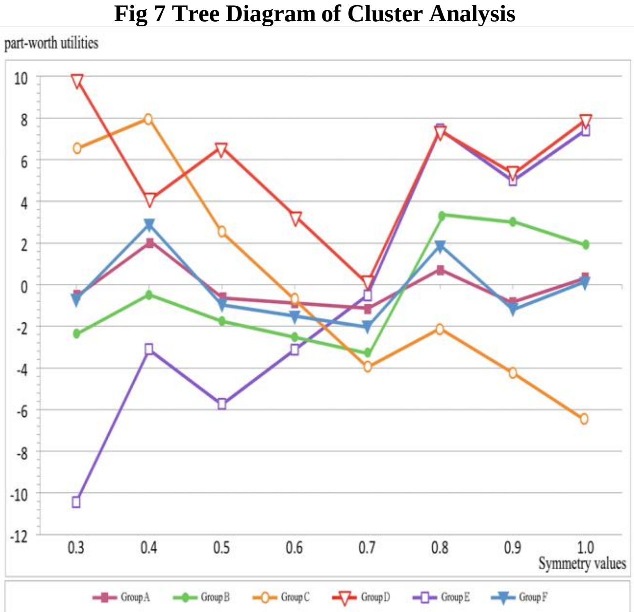

Fig 8 Part-worth Utilities of the Different Symmetry Values in Each Group

The other subjects with unique aesthetic tastes are not considered in the following analysis. The obtained clusters are marked in six color blocks with number A, B, C, D, E, and F. Based on the cluster results, arithmetic averages of subjects' part-worth utilities of each aesthetic value in each group are calculated to obtain the representative part-worth utilities of each group. At the same time, the missing data, the part-worth utilities of Symmetry 0.6 and Minimalist 0.4 for each group, was estimated by the Linear Interpolation. The part-worth utilities of each aesthetic value for the six aesthetic groups were drawn as Figure 8~10.

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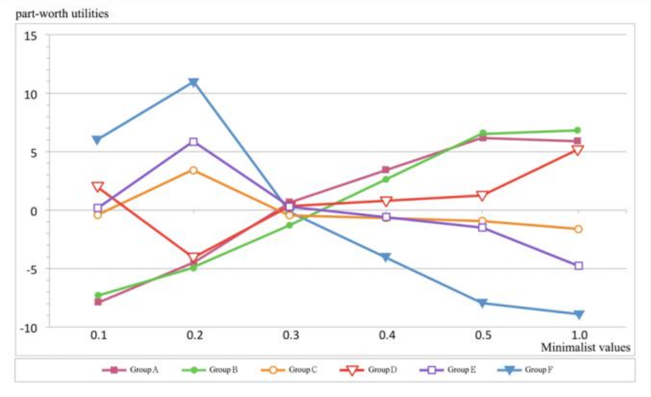

Fig 9 Part-worth Utilities of the Different Minimalist Values in Each Group

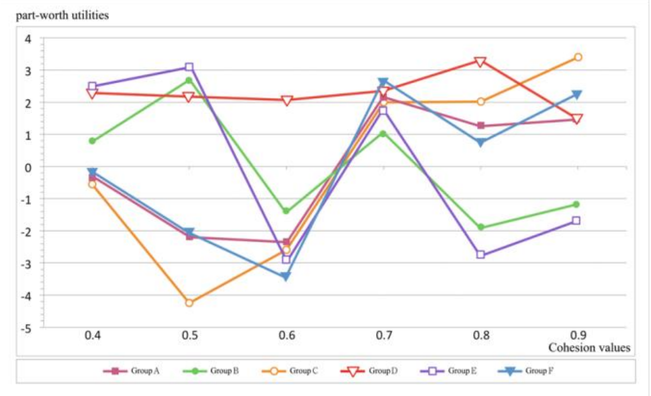

Fig 10 Part-worth Utilities the Different Cohesion Values in Each Group

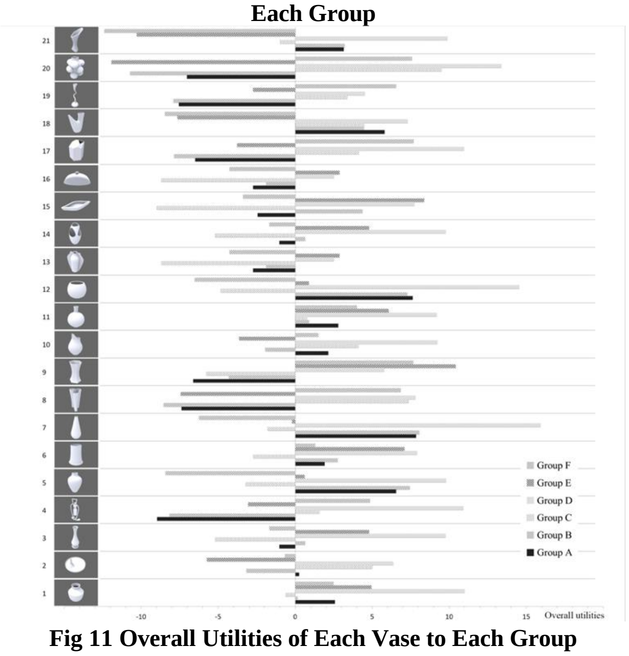

Fig 11 Overall Utilities of Each Vase to Each Group

In Group A, there is no apparent trend for the subjects on their preference of Symmetry values. When the Symmetry value is 0.4, the part-worth utility is much larger than the other values. The preference for Minimalist generally presents a positive linear increase. However, the increase tends to slow down when the Minimalist value approaches 1.0. For the Cohesion, the one in high Cohesion value is more preferable than others with low value and the maximum part-worth utility occurs at the value that equals to 0.7.

In Group B, the preference trend of the principle of Symmetry reveals that the value, 0.7, serves as a dividing point. The part-worth utilities are all increasing whether the value of Symmetry increases in the positive direction or decrease in the negative direction from 0.7. However, the increases in these two half portions are non-linear. The preference of Minimalist presents a positive linear increase. There is no apparent rule for the aesthetic principle of Cohesion, but the part-worth utility of value, 0.5, is much larger than the other values.

In Group C, the preference of Symmetry generally presents in a way of Reversal Quality. It can be observed that the subjects prefer the most when the Minimalist value is 0.2. For the preference of Cohesion, the value that equals to 0.5 is the point of the lowest preference and the preference increase is apparent particularly when the Cohesion value increases.

In Group D, the subjects do not have a definite preference trend toward the principle of Symmetry, and there is a particularly apparent preference for the extreme Minimalist values, 0.1 and 1.0. For the preference of Cohesion, although the overall part-worth utilities are all above zero, it can still be divided into three line segments: the Reversal Attractive Quality between 0.4 ~ 0.6, the Attractive Quality between 0.6 ~ 0.8, and the Reversal Attractive Quality between 0.8 ~ 0.9.

The preference of group E for the overall Symmetry, the subjects prefer high Symmetry value. The maximum Minimalist value equals to 0.2. Either increasing or decreasing of the Minimalist values lead lower and lower degree of preferences. The preference model for Cohesion is similar to Group B, and there is not a definite rule.

In Group F, there is no definite trend for the subjects on the preference model in the principle of Symmetry. The part-worth utilities are high when the Symmetry values are 0.4 and 0.8, and the rests are mostly negative. The preference for Minimalist has a maximum value at 0.2, and the part-worth utility will become smaller when the Minimalist value either increases or decreases. The part-worth utility of Cohesion 0.6 is the minimum, and the part-worth utilities of higher Cohesion values still possess the trend of higher preferences although it is not linear. Figure 11 shows the overall utilities of each vase to each group.

D. Verification and Design Application

To ensure the preference models of the six groups that have been constructed indeed possess the capability of prediction, 3 additional vases, excluded in the 21 representative vases, are entered into the verification based on the schematic of the selection concept and repeat the experiment steps described previously. The four subjects have randomly selected from each aesthetic group to conduct the questionnaire. Based on the calculation of the part-worth utilities of each group on each aesthetic values, the overall utilities of the 6 vases for verification can be summed up. By comparing the average actual ranking and the predicted ranking by calculation, it can be observed that the average actual ranking values are all

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within ± 1.5 to the corresponding values. Therefore, the prediction is correct to a certain degree.

For the design application, a vase evaluated by a target group as the medium preference originally is improved to achieve the group's preference by adjusting the aesthetic values. In the study, the vase number 3 as the medium preference in Group A is selected as the application case randomly. Via the adjustments of different physical parameters in the three stages, the values of Minimalist, Cohesion, and Symmetry can reach the most preferred levels of Group A, and the vase form complies better with the aesthetic taste of Group A. The final design proposal with the details is shown in Figure 12.

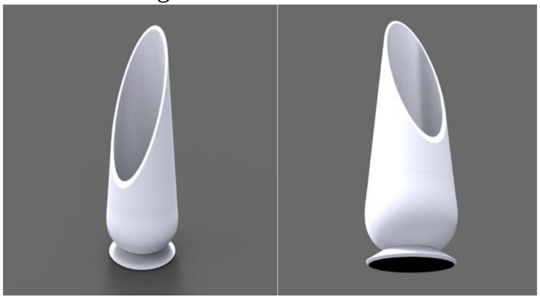

Fig 12 The New Vase Form in Better Aesthetic Taste of the Target Group

V. DISCUSSION

In accordance with the results, the applicable aesthetic principles of vases include Symmetry, Minimalist and Cohesion. Depending on the two indices of Pearson's R and Kendall's tau in the conjoint analysis, it can be verified that the subjects indeed possess the established preference models when choosing the preferred form of vases and then the concept of market segmentation was utilized by the cluster analysis to divide the subjects into six groups with various aesthetic perceptions based on the differences in the part-worth utilities, perceived by the subjects on the three types of aesthetic principles. The results are further utilized to construct the figures of the form preference models of each group. With the figures of preference models, the Reversed Engineering can be utilized to detect the preference values of the groups on the designed vase forms. This approach can also be applied to the form design and renovation, Also, it provides the modification of the form designs with the right direction and a correct basis.

The construction of preference models in the study is based on the three principles which are only applicable to vases. In the future, more aesthetic principles and values may be included to make up the deficiency. Additionally, the study focuses on the vases, but the approach of preference models may be applicable to the different kinds of products. It is a matter can be further investigated and discussed. On the design application, the rational evaluations of aesthetic measures have been selected as the basis which is more suitable for the prediction and detection of the reversed engineering way. However, how to rapidly apply this approach to top-down designs and generate new forms with the target aesthetic values is still an issue to be developed and advanced. Future studies regarding these problems could be addressed in order to offer more advanced and sophisticated methodology for analyzing consumer preference.

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