A New Method of Smartphone Appearance Evaluation Based on Kansei Engineering

Wenjun Hou[1,2], Zhiyang Jiang[1,2(✉)], and Xiaohong Liao[1]

[1] School of Digital Media and Design Art, Beijing University of Posts and Telecommunications, Beijing, China
janejiang595@gmail.com

[2] Beijing Key Laboratory of Network and Network Culture, Beijing University of Posts and Telecommunications, Beijing, China

Abstract. As the smartphone market gradually becomes mature, smartphone appearance has become a prime factor in the consumer's decision-making process when purchasing a smartphone. Based on the methodology of Kansei engineering, this paper aims at constructing a Kansei image rating system to evaluate smartphone appearance. Firstly, an initial Kansei image scale was constructed containing 36 word pairs selected from over 700 emotional ideological words from Chinese literature and interview. Secondly, the semantic difference experiment was conducted over 50 subjects to evaluated six smartphones with different appearances using the initial scale. Thirdly, three statistical analyses were applied to the experimental data to further optimize and weight the Kansei image scale, including project analysis, factor analysis, and AMOS structural equation modeling. Finally, we applied the overall weighed Kansei image rating system to evaluate the performance of the six smartphones on four dimensions: exquisiteness, balance, color and reliability. The results show that our weighted Kansei image rating system can be applied to future smartphone appearance evaluation and marketing prediction.

Keywords: Kansei image scale · Smartphone appearance · Project analysis · Factor analysis · AMOS structural equation model

1 Introduction

As the modern industrialization matures, consumers are paying more attention to the appearance of products, including home appliances, automobiles, daily necessities, etc. Customers forms their awareness of consumption over their increased experience of purchases, and they are more willing to pay for the products or services that satisfy their aesthetic needs. In addition, consumer demands for products or services have shifted from basic material needs to perceptual needs. Whether products or services bring consumers the sense of pleasure and

A. Marcus and W. Wang (Eds.): HCII 2019, LNCS 11583, pp. 439–449, 2019.
https://doi.org/10.1007/978-3-030-23570-3_32

satisfaction is becoming more and more important. Therefore, it is necessary to study the consumers' perceptual cognition of a product. However, it is difficult for a single human individual to let others understand our senses accurately. Our subjective response to objects can be affected by our past memories, emotions, current environment and state of mind. So for the manufacturers, how to evaluate the response of a new product from the market and from most of the consumers? This paper will conduct a detailed study from this perspective.

Kansei engineering is an approach to derive consumers' affective needs of services and products [1,2,4]. Kansei engineering's ultimate goal is to build up a certain corresponding relationship between a specific product design element and the perceptual reaction of observer, and find the product design which can meet user's different needs the most by studying the influence of different product design elements on human perceptual emotion [5,6]. In a word, as a new research method, the Kansei engineering can do quantitative analysis on the human perceptual emotion [3].

2 Methodology

2.1 Collection and Selection of Kansei Image Word Pairs

Based on Kansei engineering research methods, first we need to describe the consumers' perceptual evaluation on the product appearance systematically, that is to construct a standard set of Kansei Image Scale, which covers as many images when consumers see a product as possible. We collected nearly 100 Chinese literatures related to Kansei engineering to extract the undeleted image vocabulary statistics, as shown in Table 1:

Table 1. Some image vocabulary in chinese literature, translated to English.

elegant—vulgar	concise—complicated
fluent—stiff	light—heavy
trendy—quaint	generous—stingy

In this way, 650 image vocabularies were collected. In order to check its completeness, we chose six smartphones and recruited 15 subjects for interviews, asking them to use adjectives to describe the appearance of smartphone in front of them. Before each interview, the researcher make sure the phone is turned off, wipe the surface of the phone with cotton cloth, and place it on the spinning stand. During the interview, subjects can only observe the phone instead of touching it, and the researcher records the adjectives in the description of a specific product. Based on the results of this interview, we acquired a total of 200 adjectives, in which 150 adjectives overlaps with the previously acquired image vocabularies. As for the remaining 50 words, they also have similar words in the vocabulary, however we still add them at this point. Thus, the image vocabulary has been expanded from 650 to 700.

Second, we sort these Kansei image vocabularies through the card sorting experiment and eight designers from the industrial design areas. There are three principles of the sorting: (1) the selected vocabulary used for describing the product is appropriate; (2) we just keep one word among the words with similar semantic meanings; and (3) the final selected vocabularies should basically contain all possible description of a product. The outcome of this are 36 word pairs, as shown in Table 2. For the convenience of data processing, the words were numbered. We use this as the initial Kansei Image Scale.

Table 2. Initial Kansei Image Scale

w1	rough	exquisite	w19	simple	gorgeous
w2	complicated	simple	w20	dreary	festive
w3	conservative	innovative	w21	easygoing	rigorous
w4	low-end	high-end	w22	business	casual
w5	mild	hard	w23	thick	light
w6	scattered	integrated	w24	bloated	slim
w7	irregular	regular	w25	ugly	beautiful
w8	unbalanced	coordinated	w26	realistic	science fiction
w9	old-fashioned	faddish	w27	trendy	classic
w10	humanities	technology	w28	feminine	masculine
w11	cheesy	elegant	w29	fancy	practical
w12	stingy	generous	w30	cold	lovely
w13	estrangement	affable	w31	calm	excited
w14	childish	mature	w32	difficult	easy
w15	old	young	w33	dim	bright
w16	national	international	w34	squared	rounded
w17	vulnerable	resilient	w35	concrete	abstract
w18	dirty	clean	w36	cheap	expensive

2.2 Smartphone Morphological Analysis and Semantic Difference Experiment

For industrial products, its shape is presented by the appearance of the product image, which is collected from the aspects of visual sense. In order to verify the reliability and validity of perceptual image and vocabulary, we need to choose one product to conduct reverse user test. Therefore, we choose six kinds of models of smartphones for research, as shown in Fig. 1. The reason why we choose smartphones, rather than other kinds of products for research is that the smartphone appearance aesthetic differences is a very large factor in the consumer decision-making process.

Fig. 1. Six smartphones for research

The smartphones to be tested are numbered with phone 1, 2, 3, 4, 5 and 6. The appearance of several smartphones is described by morphological analysis, as shown in Table 3.

Table 3. Morphological analysis on the six smartphones

	Modeling characteristics	Body color	Material
Phone 1	Screen size: 6 in. Thickness: 7.5 mm 2.5D arc glass panel Screen and body rounded together	Gold	Aerospace titanium alloy & leather
Phone 2	Screen size: 6 in. Thickness: 7.9 mm Arc back	Silver	Metal
Phone 3	Screen size: 5 in. Thickness: 8.1 mm All-surrounded back	Black	Plastic
Phone 4	Screen size: 5 in. Thickness: 7.55 mm Dual micro-arc design	White	Magnesium alloy
Phone 5	Screen size: 5.7 in. Thickness: 6.9 mm Hyperbolic side screen	Silver	Metal & glass
Phone 6	Screen size: 4.95 in. Thickness: 7.53 mm	Black	Alloy & high hardness glass

Among them, the body of smartphone 1 has Xiangyun texture (a traditional Chinese texture), and the rest of the phone has no texture pattern. In this study, we recruited 30 subjects to conduct semantic differential experiments. Researchers put the phone in a random order in front of the subject. Touching is prohibited as before, and researchers will help subject when they need to turn smartphones over. The subject is requested to give scores for each word pair (topic) in the Kansei image scale, on the range of $\{-2, -1, 0, 1, 2\}$, on each of the six phones. They should compare all six phones when giving mark on each topic, and it is necessary to give reasons when using negative words. After finish the marking of one topic on all six phones, they move on to the next topic. What should be emphasized is that, before experiment, we use stickers similar in the color of the phone to cover the logos on the surface, in order to avoid the brand effect which influences the experimental subjects and causes derivation in experiment.

2.3 Revise the Scale Using Experimental Data

Project Analysis. The key purpose of project analysis is to test the appropriateness and reliability of the experimental scale or a particular term in the scale. The difference between project analysis and reliability test is that, the purpose of reliability test is to check the reliability degree of the entire scale or concepts containing multiple terms in the scale. The test of project analysis is to explore differences between any two terms of all the subjects, or to test the homogeneity between terms. Project analysis results provide a scientific basis for whether to modify or delete a term in the image scale.

Through the method of project analysis, this experiment examines the reliability of 36 word pairs, and excludes the word pairs with low relevancy. We choose two common project analysis methods to perform this step, namely the critical ratio method and the average Pearson analysis method. The excluded nine word pairs are w5-mild-hard, w22-business-casual, w27-trendy-classic, w28-feminine-masculine, w29-fancy-practical, w33-dim-bright, w34-squared-rounded, w35-concrete-abstract, and w36-cheap-expensive. The Kansei Image Scale remains 27 word pairs.

Factor Analysis. Constructing an ideal Kansei Image Scale can make the product appearance evaluation easier, and can help the evaluation to reach a reasonable conclusion, which has a great reference value in the actual product design iteration process. This step begins with a factor analysis based on the project analysis, transforming factors that affect the aesthetic appearance of the product into a few, and building structural equation models using AMOS.

We conduct a factor analysis on the Kansei word pairs, which are the variables that forms the Kansei Image Scale. The tool for factor analysis is SPSS. First of all, the KMO test and the Bartlett's test of sphericity are performed on the factor analysis data, which are shown in Table 4. The result shows that the KMO value is 0.914. According to the KMO metric, a KMO above 0.90 is considered extremely suitable; 0.80 to 0.90 is considered very suitable; 0.70 to 0.80 are considered suitable; 0.50 to 0.60 are considered less suitable; Less than 0.50 will be considered not suitable. Therefore, the original 27 variables are very suitable for factor analysis. The probability of the significance of the statistic value of x of the Bartlett's test of sphericity in the table was 0.000, less than the significance level of 0.001, thus rejecting the null hypothesis of the Bartlett's test for sphericity, which is considered suitable for factor analysis.

The scree plot of factor analysis visually shows the size changes of 27 eigenvalues, as shown in Fig. 2. Scree plot of factor analysis can also help us determine

Table 4. KMO and Bartlett's test

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy		.914
Bartlett's test of sphericity	Approx. Chi square	4277.750
	Degree of Freedom	351
	Significance	0.000

the optimal number of factors. The abscissa of the scree plot is represented by the number of factors, while the ordinate is the eigenvalue. The first four eigenvalues are relatively large. From the fifth eigenvalue, the become smaller, and the connected line of the eigenvalues also become steady.

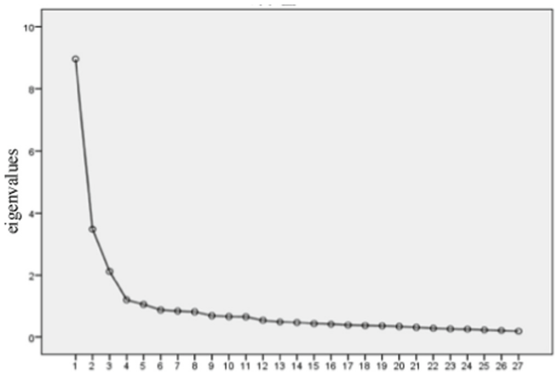

Fig. 2. Scree plot of factor analysis

After the first four factors were extracted, the rotation analysis was performed to reduce the comprehensiveness of the factors. Then, each vocabulary was classified according to the load values on the four factors. The classification results are shown in Table 5. The category represented by factor 1 is exquisiteness, factor 2 is balance, factor 3 is color, and factor 4 is reliability.

Table 5. Classification of the factors

	First-level factor	Second-level factor
Scale	Exquisiteness	w3, w9, w26, w4, w1, w11, w15, w16, w25
	Balance	w7, w32, w2, w8, w6, w13, w18, w24
	Color	w14, w12, w21, w23, w17
	Reliability	w20, w19, w31, w30

Table 6 shows the factorial covariance matrix of the four newly generated factors, which shows that after the rotation, the four factors are still orthogonal.

Table 6. Factor covariance matrix

	1	2	3	4
1	1.000	.000	0.000	.000
2	.000	1.000	0.000	.000
3	0.000	0.000	1.000	0.000
4	.000	.000	0.000	1.000

Scale Revision by AMOS Structural Model. The starting point of the structural equation model is the established quantitative causal relationship between the observable variables according to the assumed causal relationship. At the end point, the relationship between the variables is clarified by the path map with path coefficients. It is assumed that the model is usually established according to the specific background, and each path corresponds to some interpretable practical meaning. Therefore, a deep understanding of the practical problems and the correct grasp of the relationship between variables and the constructed variables are the prerequisites for constructing the structural equation model. The path map with path coefficients is essentially a visualization of the linear equations. It clearly presents the relationship between observable variables and latent variables, as well as relationships between each latent variable. It is also a multivariate statistical method whose essence is a generalized general linear equation.

The steps to construct structural equation model are: model identification, model estimation, model evaluation, model modification and model interpretation. Finally, after satisfying all the indicative conditions, the results acquired are as shown in Fig. 3.

From the path map with path coefficients, the correlation between the second-level observable variable and the first-level observable variable, as well as the correlation between the first level observable variable and the overall Kansei Image Rating, can be obtained, as shown in Table 7.

From the path map with path coefficients, we can see that among the first-level variables that directly affect the product's Kansei image, the correlation coefficient of exquisiteness is the highest (1.00), followed by balance (0.41) and reliability (0.36). The correlation coefficient of color is the lowest (0.29).

3 Results

Through the analysis above, we can conclude that there are four dimensions which affects the product's Kansei image: exquisiteness (correlation coefficient 1.00), balance (correlation coefficient 0.41), reliability (correlation coefficient 0.36) and color (correlation coefficient 0.29). In the semantic difference experiment, the performance of the six smartphones with different appearances on these four dimensions is evaluated by calculating the score average on each

Table 7. Weighted scale

	First-level latent variables and its path coefficient	Second-level observable variables and its path coefficient	
Overall Kansei image rating	1.00 exquisiteness	1.00	w3-conservative-innovative
		1.31	w9-old-fashioned-faddish
		0.89	w26-realistic-science_fiction
		1.15	w4-low_end-high_end
		0.94	w1-rough-exquisite
		1.26	w11-cheesy-elegant
		1.01	w15-old-young
		0.96	w16-national-international
		1.17	w25-ugly-beautiful
		0.34	w10-humanities-technology
	0.41 balance	1.09	w7-irregular-regular
		0.69	w32-difficult-easy
		1.22	w2-complicated-simple
		1.22	w8-unbalanced-coordinated
		1.33	w6-scattered-integrated
		1.18	w13-estrangement-affable
		1.00	w18-dirty-clean
		0.79	w24-bloated-slim
	0.36 reliability	1.00	w14-childish-mature
		0.89	w12-stingy-generous
		0.69	w21-easygoing-rigorous
		0.42	w23-thick-light
		0.47	w17-vulnerable-resilient
	0.29 color	1.33	w20-dreary-festive
		1.54	w19-simple-gorgeous
		1.03	w31-calm-excited
		1.00	w30-cold-lovely

Kansei image word pairs rated by 50 subjects, multiplied by the corresponding second-level variable path coefficient, and then summed up grouped by four dimensions. The results are as shown in Table 8.

Based on the rating on each dimension for each smartphone, the overall Kansei image rating of 50 subjects on six smartphones are calculated, for example:
Overall Kansei Image Rating of Smartphone 1
= Exquisiteness Score (−2.727) * Weight of Exquisiteness (1.00)
+ Balance Score (−0.452) * Weight of Balance (0.41)
+ Reliability Score (2.900) * Weight of Reliability (0.36)
+ Color Score (1.230) * Weight of Color (0.29)
= −1.51222.

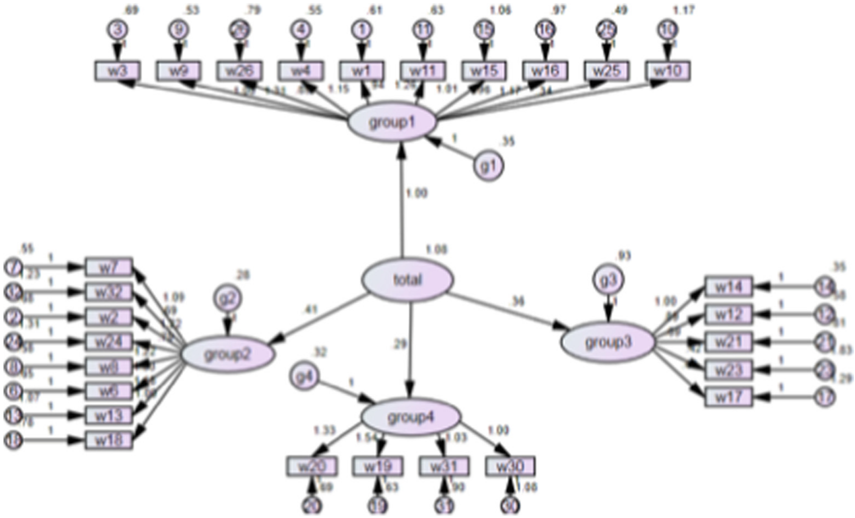

Fig. 3. Model parameters estimation results

Table 8. Weighted ratings on each dimension of 50 subjects

Phones	Exquisiteness	Balance	Reliability	Color
P1	−2.727	−0.452	2.9	1.23
P2	1.575	2.721	3.401	−2.059
P3	5.583	9.644	1.614	−1.759
P4	10.564	3.265	0.508	4.44
P5	−1.271	3.438	−1.907	2.425
P6	1.26	4.564	1.314	−2.104

The overall Kansei image rating of the six smartphones are calculated in Table 9.

Table 9. Weighted overall Kansei image rating

Phones	Overall Kansei image rating
Phone 1	−1.51222
Phone 2	3.317462
Phone 3	9.607388
Phone 4	13.37298
Phone 5	0.155737
Phone 6	2.99374

The range of Kansei image rating is (−30, 30). It can be seen from the table above that smartphone 4 has the highest overall Kansei image rating, for smartphone 4 has obtained relatively high scores in the dimension of exquisiteness and color. Smartphone 3 follows, for its score were high in the dimension of exquisiteness and balance. Smartphone 1 had the lowest overall Kansei image score. Although its score in the reliability dimension was high, but reliability is not the key factor that affects the overall score. Meanwhile, smartphone 1 has a low score in the dimensions of exquisiteness and balance, which is the reason that the overall score is low.

4 The Application of Kansei Image Scale

According to data released by the China Ministry of Industry and Information Technology, the total annual shipments of the Chinese smartphone market reached 492 million in 2017, which was 4% lower than that in 2016. This is the first time that China has seen the total volume of smartphone sales decline. It is expected that competition will be more intense in the next few years.

The saturation of smartphone market forces companies to pay more attention to produce smartphones that are well designed, functional and provide better user experience in order to expand their market.

In this paper, the Kansei Image Scale with path coefficient helps designers or mobile device manufacturers to evaluate the performance of existing products and conceptual products on the perceptual level. Also it can be used for comparison and analysis of competitive products. By assessing the product performance in the four factors which are exquisiteness, balance, reliability and color product, the quality of design can be quantified for future improvement.

Another application of the Kansei Image Scale lies in its relatively accurate prediction. Prediction regards to emotional feedback and market sales. Through the previous semantic difference experiment, we obtained the scores of six smartphones in Kansei Image Rating. Compared with user experience feedback on the e-commerce platform of smartphone, it's found that the two results maintain a high degree of consistency; In addition, we also find that the conclusions drawn from the semantic difference experiment of perceptual images are consistent with the sales of smart phone in 2017. That is to say, the merchants can estimate the market reaction and approximate sales volume of the products that have not been put on the market.

5 Discussion

There are some research points for further discussion as follows:

1. As for the initial scale model, whether the application scope of the initial Kansei Image Scale can be extended to the appearance evaluation of other industrial products? In this paper, the word pairs of initial Kansei image were selected from more than 700 words that covered the field of female cell

phone modeling, iPhone modeling, Nokia cell phone modeling, display modeling, car interiors, car front, tablet, PC modeling, exercise bike, toys, Chinese furniture, microwave ovens, student apartments, ceramic products, web pages, commercial vehicles, clothing, shoes, car seats, door handles, sewing machines. The research and verification only applied to appearance design of smart phones. The results show that the reliability and validity of the scale are good. Therefore, it deserves to be discussed if the scale can play a role in product positioning and prediction of user feedback and market sales volume of other industry products

2. As for improved scale model, the adaptability index of the fitted model can be further optimized and the model can be further adjusted. Currently, there are noticeable difference in the number of the second-level variables corresponding to the four first-level variables.

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