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EVALUATING APPEARANCE-RELATED PRODUCT PROTOTYPES WITH VARIOUS FACIAL CHARACTERISTICS

Cheng-Hung LO (1), I-Jan WANG (2), Szu-Hao HUANG (2), Chih-Hsing CHU (2)
1: Chang Gung University, Taiwan; 2: National Tsing Hua University, Taiwan

ABSTRACT
Design prototype evaluation is a key process in new product development. The characteristics of the product users are as important as the design features for products that might alter the appearances of these users. This paper proposes a product evaluation scheme that integrates design features and user facial characteristics in one evaluation process. We implement an experimental scheme to evaluate the design prototype of glasses frames. 3D scanning technology is applied to capture the facial features of users and reconstruct realistic 3D face models. Those allow us to post-process individual facial feature without changing the others. In the experiment, the subjects response on three affective measures related to personality attributes: confidence, friendliness, and attractiveness, signified by the faces wearing the factorized glasses frames. The results show that changing certain design features indeed influences the impressions of the faces with varied facial characteristics. The proposed scheme can be employed to facilitate the design of products related to personal appearance.

Keywords: kansei engineering, emotional design, user experience, product evaluation

Contact:
Prof. Chih-Hsing Chu
National Tsing Hua University
Department of Industrial Engineering
Hsinchu
30016
Taiwan, Republic of China
chchu@ie.nthu.edu.tw

1 INTRODUCTION

Design prototype evaluation is a key process in new product development. The evaluation results often serve as a valuable input for identifying necessary design modifications. For products that might alter the appearances of their users such as facial accessories, the characteristics of these users are as important as the design features. The product studied in this paper, the glasses frame, is associated with facial characteristics. Although originally as a tool to treat sightedness problems, it is not uncommon to see people nowadays, some of whom having perfectly-normal vision, wearing glasses enhance their facial appearances. In (Langlois and Roggman, 1990), the term, "attractiveness", was firstly used to measure the aesthetic of human faces. Langlois's team collected photographs of female faces and asked a group of adult participants to rate the attractiveness of each face. A similar finding was obtained in a later work done by Slater et al (Slater et al., 1998). Some researchers applied image processing and morphing techniques to produce an ideal face model such as the "average face" in (Langlois and Roggman, 1990) and (Komori et al., 2009) or the "symmetrical face" in (Koehler et al., 2002). The synthesized faces were considered more attractive than the other un-altered faces. Many researchers focus on the social aspect and believe that facial characteristics provide important guide to personality attributes (Hassin and Trope, 2000). Indeed, there is evidence showing consistencies between self-reported and perceived personality attributes when the face is the only source of information (Penton-Voak et al., 2006). By extrapolating the facial images, Perrett et al. (Perrett et al., 1998) also found that the masculinity of faces was related to how dominant the face owner was. Most of the digitally-manipulated faces in the above literatures are 2D visual stimuli. Our work attempts to integrate the face factor in the prototype evaluation process with 3D Face Scan technology. This allows us to manipulate the synthetic faces on 3D geometrical level.

Kansei Engineering (Nagamachi, 1995), developed by Nagamachi in 1990s, is a widely-adapted approach for analyzing a user's affective responses towards the design features of a product. The Semantic Differential(SD) method (Osgood, 1957) is commonly used in Kansei studies to elicit the users' affective responses, which are recorded with the levels of the users' agreements on a group of antonyms called "bi-polar" adjectives describing the design features of a product. Kansei has been applied to investigate a wide range of product design issues, from the design of small products such as consumer electronics (Chuang et al., 2001) to larger ones such as car interiors (Jindo and Hirasago, 1997) or industrial machineries (Nakada, 1997). More recently, Hsiao et al. (Hsiao and Chen, 2006) studied the relationship between product profiles and affective responses for large, medium, and small products. The results showed that there were shared affective responses to certain design features across different products. Lo and Chu (Lo and Chu, 2009) proposed a parametric approach that explicitly defines the profile of glasses frames as Bézier curves to study users' affective responses in accordance with the profile variations. The method allowed them to predict a user's affective responses with the regression models parameterized with the design factors (the frame's profile). These studies address the relationships between design features and affective responses. However, most of them do not focus particularly on products related to a person's appearance. In one of Lo and Chu's following studies (Lo and Chu, 2012), they suggested using socially-oriented affective measures to evaluate appearance-related products. Facial shape was included in their study to investigate how the design of glasses frames influences the appearances of difference facial shapes. This paper extends their work to include more facial features such as the eye distances and eye rotating angles.

2 EVALUATION SCHEME

Our Kansei-based evaluation scheme is carried out in the form of a factorial experiment (Montgomery, 2006). This experiment technique allows us to study the effects of multiple independent variables at the same time. The independent variables are manipulated by the means of adjusting the predefined levels of selected factors. With the factorial approach, one can examine how those variables individually and interactively influence participants' responses. The factors investigated in our experiment include facial characteristics and design features of glasses frames. The responses are thus the perceived levels of selected affective measures.

2.1 Representative 3D Face models

We recruited a total of 70 University students (male: 35, female:35) from 18 to 25 years of age to participate in the face selection process. A frontal photograph was taken for each student with a neutral expression. All of the students were asked to remove facial accessories or any item that may obscure facial features. They were also requested to wear hair nets when the photo was taken. All of the facial portraits were taken under the same lighting condition, background, and distance.

From the collected literatures and magazines, we find that there are generally 6 types of facial shape identified by the practitioners working in cosmetics. These include oblong, square, triangle, round, oval, and rectangle. We used these facial shapes as the seeding shapes. Each participant was asked to classify the 70 facial portraits into the 6 facial shape categories. After gathering the classification results of all of the participants, we computed the probabilities of each face to be recognized as the 6 facial shapes. Therefore, out of the all 70 faces, we considered to use those having the highest chance to be categorized into one particular facial shape (i.e. agreed by most of the participants). They turned out to be the faces belong to the triangular group. We then selected 2 male and 2 female faces in this group. We then used the 3D face scan system, LT 3D FaceCam, developed by Logistic Technologies Co. Ltd, to capture their facial geometries and build the corresponding 3D facial models. The original photographs and 3D models of the four representative faces are shown in Figure 1. These four 3D face models served as the face factor in the factorial experiment.

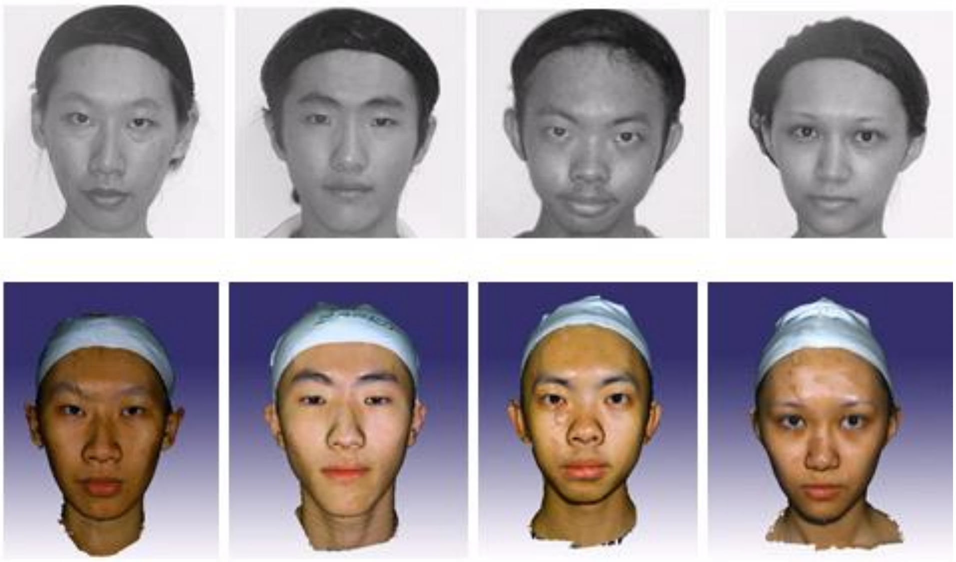

Figure 1. The representative faces and their 3D models

2.2 Representative 3D Face models Facial feature manipulation

The facial features to be manipulated were the eye distance and eye rotating angle. For calculating the eye distance, we used the inner eye corners as the reference points. According to the 3D head anthropometry database of the labour workers (18~30 years old) in Taiwan (Yang, 2002), the average eye distance is 32.3 mm with the standard deviation of 3.6 mm. We used the standard deviation as the base unit to adjust the eye distance. The eyes on the 3D face models were then moved inward with 3 units (21.5 mm) and outward with 6 units (53.9 mm) to produce models with varied eye distances.

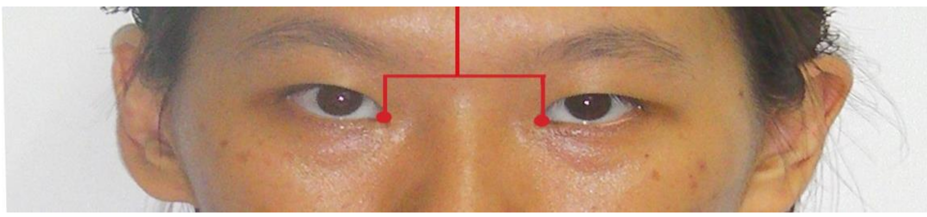

Figure 2. Inner eye corners for calculating the eye distance

In terms of eye rotating angle, we defined it as angle between the line connecting the inner-outer eye corners and the horizontal line. From the data in the same database, we computed the average eye rotating angle and the standard deviation. They turned out to be 1.5 degree and 4.41 degree accordingly. The eyes on the 3D face models were also rotated with +/-1 standard deviations (-2.91 and 5.91 degrees) to produce the models with varied eye rotating angles.

2.3 Facial feature manipulation

We adopt Lo and Chu's glasses frame model (Lo and Chu, 2009), which decomposes a frame into adjustable components such as rims and temporals (as shown in Figure 3). The components can then be re-assembled as the customized frame prototypes.

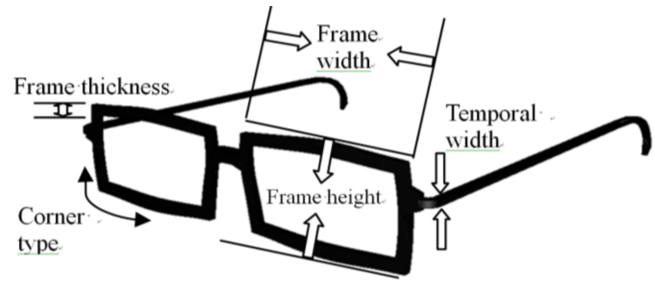

Figure 3. The glasses frame prototype and its components

From all the components, we selected two that were found to be most significant in changing a user's affective responses in Lo and Chu's study (2012), which are the rim aspect ratio and frame thickness. The two components were varied and combined to generate the factorized glasses frame prototypes. The other components remained unchanged. Combing the variations of the two components yielded four prototypes as shown in Figure 4.

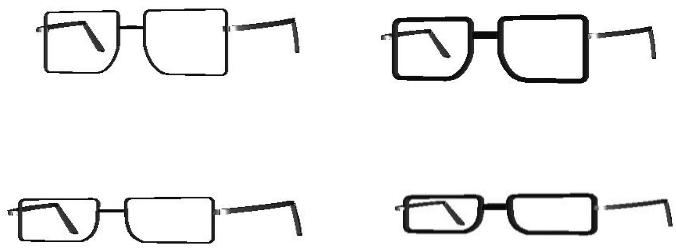

Figure 4. The glasses frame prototypes used in the experiment

2.4 Affective measures

As described earlier, the affective responses are recorded via the means of evaluating the levels of agreement on the relevant adjectives. Our work is concerned with the affective effects invoked by the design features of a product that alters a person's appearance. From the literatures reviewed in the introductory section, we selected three appearance-related measures to represent the affective responses:

- Level of Confidence
- Level of Friendliness
- Level of Attractiveness

2.5 Experiment procedure

There are a total of 144 visual stimuli to be rated in the experiment. The visual stimuli were presented as MS Powerpoint slides. A screenshot of how the visual stimuli were presented is shown in Figure 5. Each slide contains the pre-made animation of a 3D face fitted with the glasses frame prototypes (bottom left), five static views of the same virtual model (top), and the corresponding original face (bottom right). We carried out the experiment with the same group of participants in the face selection process. The experiment was proceeded with the following procedures: The experimenter firstly explained the purpose of the experiment. A demonstration was given to show how to control the viewing of the visual stimuli. Each participant was given one pre-trial to practice the viewing control. In addition, they were given a questionnaire to record their responses. Each affective measure is accompanied with a 7-position Likert-type scale, labelled from -3 to +3 with 0 at the middle. Each participant was requested to rate how confident, friendly, and attractive a factorized face appeared to be against the original faces.

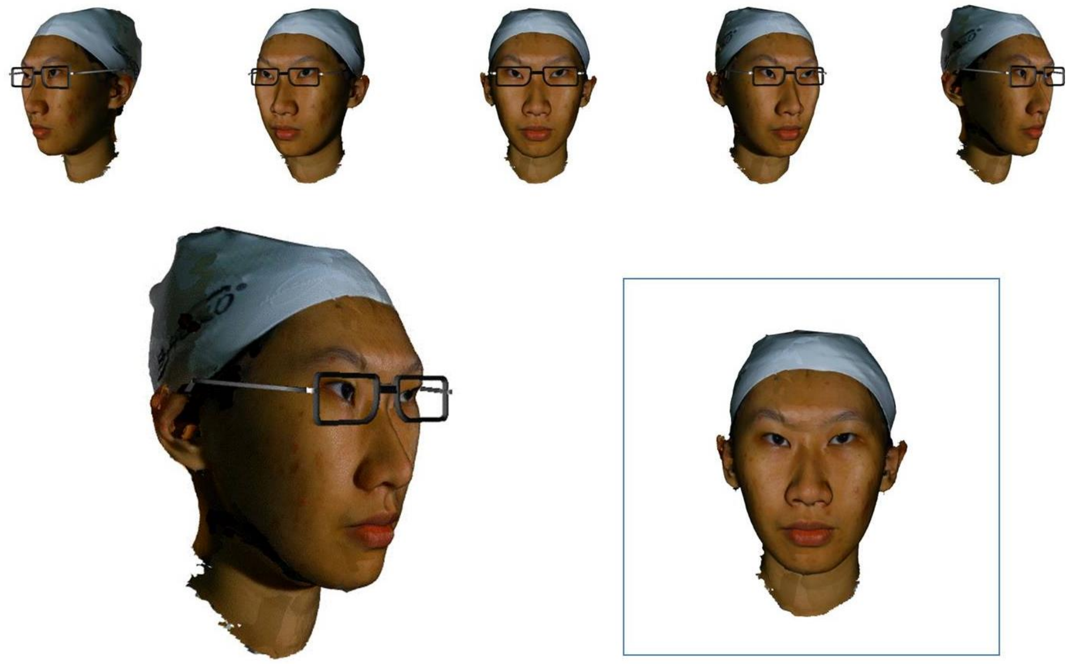

Figure 5. A screenshot of the visual stimuli

3 RESULTS

The data is analyzed with Factorial-ANOVA (F-ANOVA). The F-ANOVA analysis helps us identify whether the experimental factors individually and interactively produce statistically significant effects in changing the participants' affective responses. A probability measure called p-value calculated from ANOVA-based tests determines the statistical significance. We follow the convention in most statistical analysis (Field, 2005): If $p < 0.05$, varying the corresponding factor significantly affects the participants' judgments on the affective measures. On the other hand, F is a measure of the ratio between the effects caused by the systematic variations (our manipulations of the factor levels) and the unsystematic variations (any other unknown random factors). In general, the F value should be larger than 1 to conclude that the differences in the subjects' responses are due to the systematic manipulations. The results of the analysis are shown in Table 1.

Table 1. The F-ANOVA analysis results

	Confidence		Friendliness		Attractiveness	
	F	p	F	p	F	p
Face	6.33	**0.001**	6.35	**0.001**	1.79	0.153
Angle	0.27	0.766	0.58	0.560	0.27	0.761
Aspect ratio	0.03	0.867	1.32	0.254	0.32	0.570
Frame thickness	0.05	0.824	0.01	0.932	0.03	0.872
Distance	2.79	0.066	1.66	0.195	5.86	**0.004**
Face*angle	0.37	0.897	0.47	0.832	0.42	0.864
Face* aspect ratio	0.19	0.903	0.27	0.848	0.29	0.830
Face*frame thickness	0.04	0.988	0.37	0.775	0.18	0.908
Face* distance	0.69	0.662	0.17	0.985	0.43	0.855
Angle* aspect Ratio	0.4	0.674	0.82	0.444	0.05	0.955
Angle*frame thickness	15.99	**0.000**	1.68	0.191	9.84	**0.000**
Angle*distance	16.78	**0.000**	3.17	**0.017**	14.16	**0.000**
Aspect ratio*frame thickness	19.57	**0.000**	9.30	**0.003**	21.22	**0.000**
Aspect ratio*distance	2.27	0.109	0.46	0.630	0.20	0.823
Frame thickness*distance	0.04	0.963	3.14	**0.047**	2.49	0.088

As shown in Table 1, the face factor alone significantly affects the perceived confidence and friendliness. Note here that the participants were evaluating all three affective measures against the original faces i.e. without glasses frames. Therefore, the changes in the perceived confidence and friendliness brought by wearing glasses seem to vary with individual faces. However, there is no significant difference found for the face factor on the perceived attractiveness. The eye distance is another factor that invokes significantly different responses on the perceived attractiveness. With regards to the interactional effects, the different combinations between the eye rotating angle, frame thickness, eye distance, and rim aspect ratio produce significantly different effects on the perceived confidence and attractiveness. The perceived friendliness, on the other hand, is significantly affected by the interactive changes between the rim aspect ratio and frame thickness. These statistical significances indicate that the participants reacted differently on certain individual factors and their combinations. We will discuss more details about the effects of specific factor levels in the following sections.

3.1 Confidence

The main effects of the experiment factors can be seen more clearly in Figure 6. The levels of each factor are marked on the horizontal axis, whereas the vertical axis represents the average affective ratings. At a glance on the figure, wearing the frames generally increases the perceived confidence (all above 0). It elevates most the perceived confidence of Face 1 but produces little effect on Face 2. The effects of the other factors are not as significant except for the eye distance, of which the medium level has produced the strongest improvement among the three.

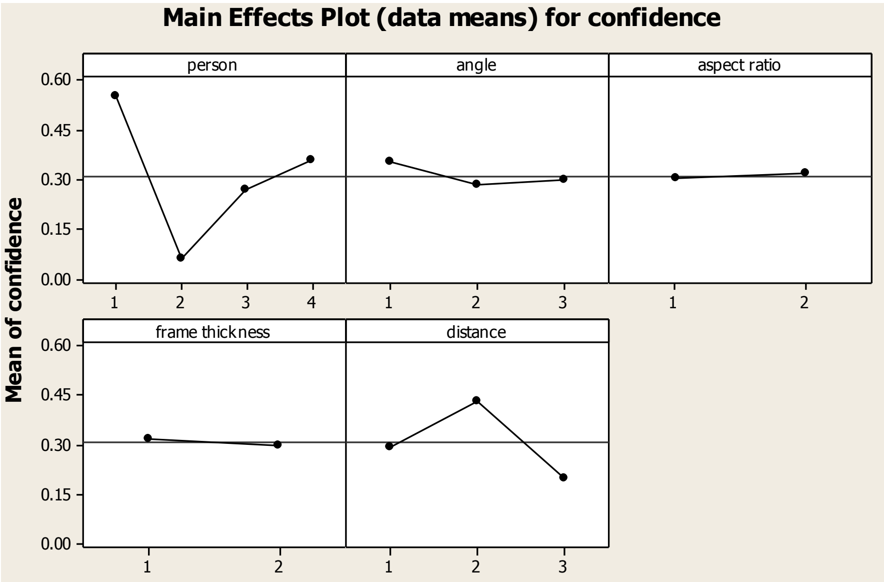

Figure 6. Mean plots of the main effects on perceived confidence

The effects of each factor against the others are shown in Figure 7. We will discuss the statistically significant ones between the facial and design features. For example, between the eye rotating angle and frame thickness, the thicker frames increases the perceived confidence of the faces with inverted eye rotating angles but reduces those with the other two eye rotating angles.

3.2 Friendliness

For the perceived friendliness, we notice that there seem to be a trend opposite to what have been observed for perceived confidence. As shown in Figure 7, with glasses frames, Face 2 gains the biggest difference on the perceived friendliness. The friendliness of Face 4, on the other hand, is least improved. For the rim aspect ratio, the perceived friendliness decreases when it gets to the higher factor level, i.e. the larger rims, which slightly increase the perceived confidence, however. On the other hand, the eye distance seems to produce a similar effect on these two affective measures.

In Figure 8, we can see how the factors work interactively on the perceived friendliness. In terms of the statistically significant effects, the combinations of different rim aspect ratios and frame thicknesses yield different affective responses. When wearing the smaller rims, increasing the frame thickness causes a decrease on the perceived friendliness of the faces. When wearing the larger rims, increasing the frame thickness elevates the perceived friendliness of the faces.

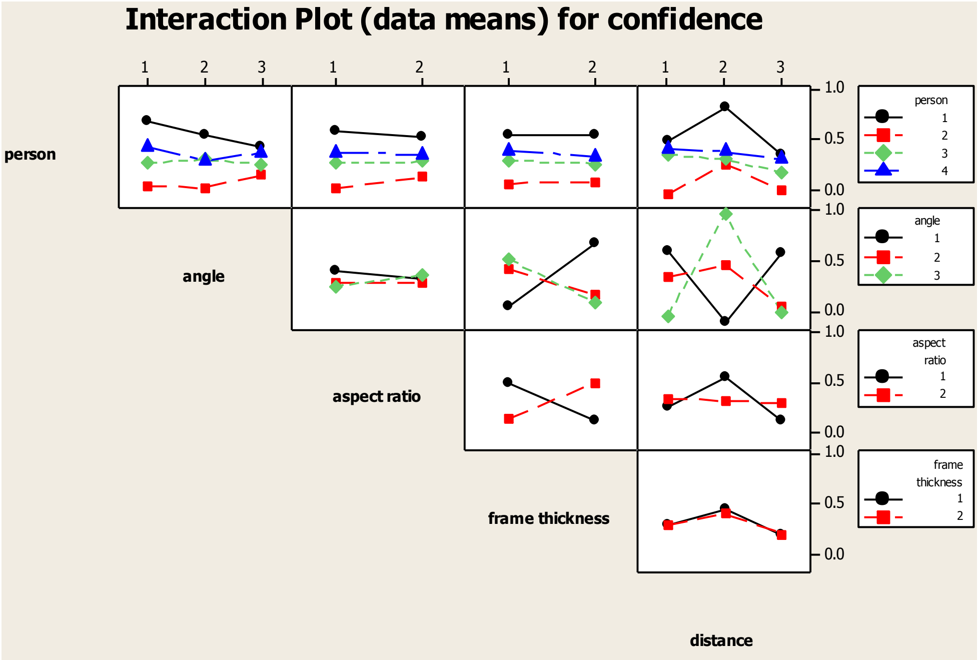

Figure 7. Interaction plots on perceived confidence

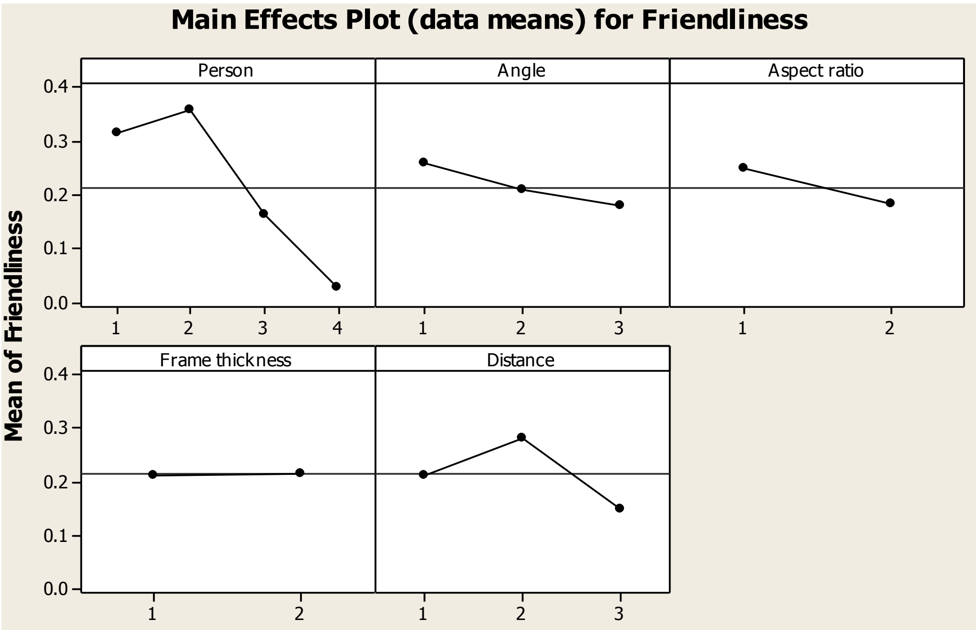

Figure 7. Mean plots of the main effects on perceived friendliness

3.3 Attractiveness

From the mean plots shown in Figure 9, we can see that wearing glasses have varied effects on the perceived attractiveness. In terms of the face factor, the attractiveness of Face 1 is increased by wearing glasses. However, it produces the opposite effect on the other three faces. Changing the eye distances also has a significant impact on the perceived attractiveness (as shown in Table 1). Specifically, both narrowing and expanding the eye distances (the medium level is the original distance) reduces the perceived attractiveness of the faces.

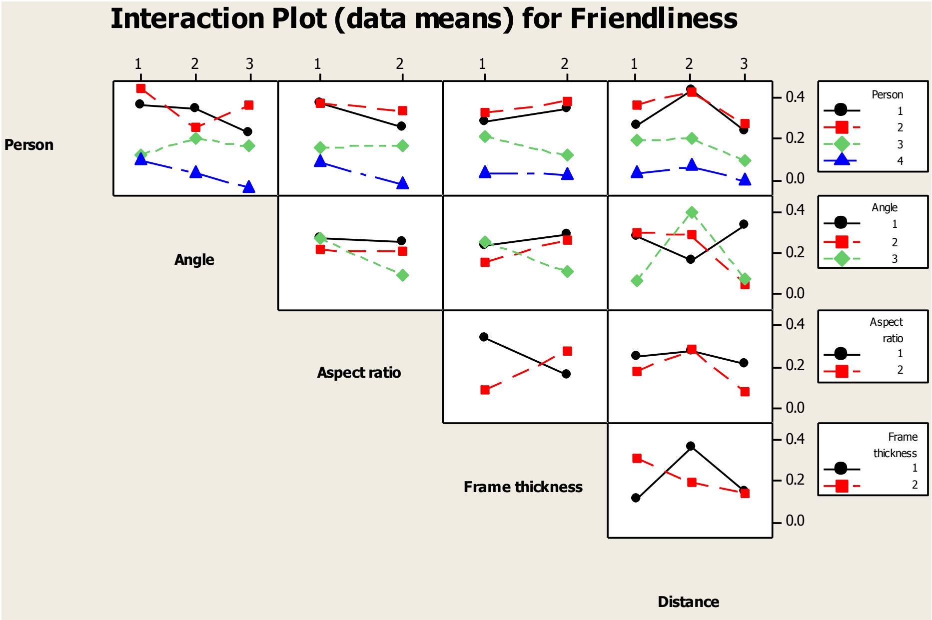

Figure 8. Interaction plots on perceived friendliness

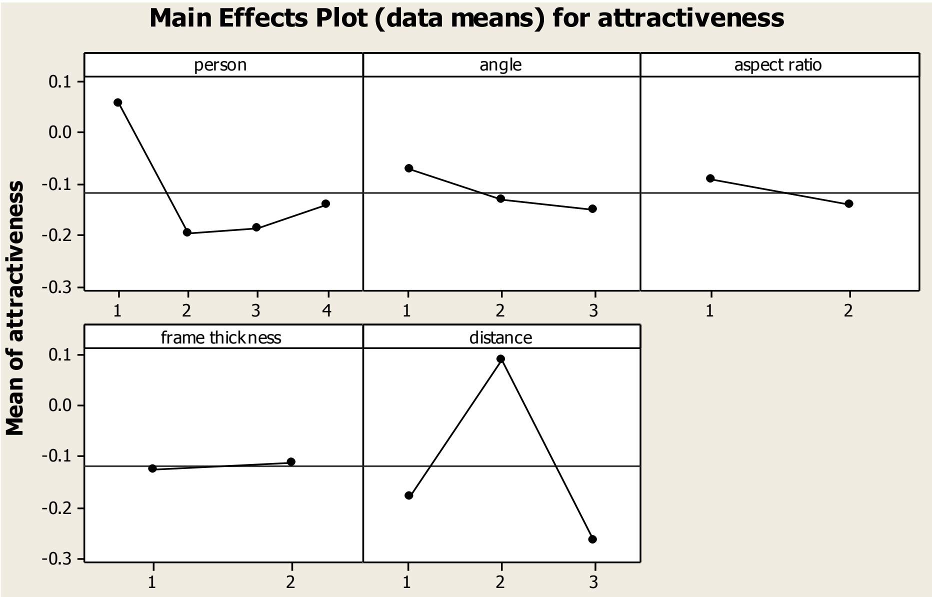

Figure 9. Mean plots of the main effects on perceived attractiveness

The interactional effects on the perceived attractiveness are shown in Figure 10. When the eyes are inversely rotated, increasing the frame thickness helps elevate the attractiveness of the faces. For the other two rotating angles, increasing the frame thickness somehow reduces the perceived attractiveness. The effects of changing eye rotating angles also varied with different eye distances. For the inverted angle, both narrowing and expanding the eye distances increase the perceived attractiveness. For the other two angles, changing the distances produces negative effects on the perceived attractiveness. In addition, increasing the frame thickness reduces the attractiveness of the faces wearing the glasses with smaller rims. When wearing larger rims, increasing the frame thickness elevates the attractiveness of the faces.

4 CONCLUSIONS

Personal appearance is an important factor in human social activities. For developing products that alter the appearances of users, it is crucial to understand how the design features interact with the characteristics of users. Using glasses frames as an example, we presented a Kansei-based evaluation scheme that integrates design and user features in the evaluation process. The evaluation utilized a factorial experiment to study multiple factors at the same time, including the design features of glasses frames as well as the users' facial characteristics. 3D Face scan technology is utilized for building digitized face models, which allow the manipulation of individual facial features while keeping the other intact. The results from the experiments reveal quite a few interesting insights. The individual face plays a dominant role in the perceived confidence and friendliness. Rotating the eye has a strong impact on the perceived attractiveness. However, wearing a frame with proper thickness helps elevate the attractiveness of the faces with inverted eye rotating angles. More facial characteristics can be investigated with the relevant products by using the proposed evaluation scheme. It should be noted here that the design problem addressed in our work is more of the aesthetics than comfortability issue. Another important part of the future work is to incorporate CAD technology and develop a affective design system for appearance-related products.

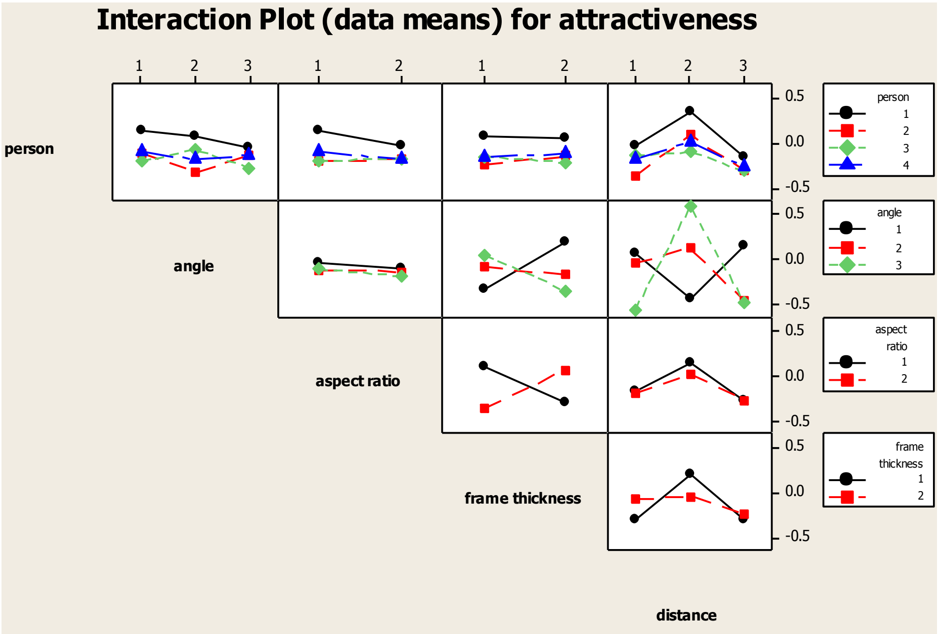

Figure 10. Interaction plots on perceived attractiveness

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