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EFFECTS OF DESIGN FEATURES ON AUTOMOBILE STYLING PERCEPTIONS

Lin-Lin Chen[1], Hsien-Chang Kang[1], and Wei-Ken Hung[2]

[1]Graduate Institute of Design, National Taiwan University of Science and Technology, llchen@mail.ntust.edu.tw

[2] Department of Industrial Design, Ming-Chi University of Technology, hwkm@ns1.mit.edu.tw

ABSTRACT

Design features such as the shape of headlights play an important role in defining the characteristic of an automobile. In this paper, we developed a method for investigating the effects of design features on the perception of automobile designs, by combining a new computer tool for fast and realistic visualization of different feature compositions in designs, and the conjoint analysis method from marketing research for analyzing the individual effects.

Four automobile design features – front grill, headlights, overall profile, and side vents – were selected for investigation. The results show that headlights and side vents have higher impacts in defining the characteristic of an automobile, than the other two design features.

It is hoped that the proposed visualization tool combined with conjoint analysis method offer a way

for designers to systematically investigate how to manipulate product shapes and features to achieve specific perceptual qualities.

1. INTRODUCTION

Systematic investigation on influences of visual features on the perception of designs is important for understanding brand image and aesthetic preference. In the automobile industry, under the intense pressure of offering greater product varieties at competitive prices, car companies have increasingly employed platform sharing strategy, where different brands and models share the same basic platform (van Grondelle and van Dijk, 2004; Heikkilä et al. 2002). Examples of automobile platform sharing include the Volkswagen A4 platform, on which the Volkswagen Golf, the Audi A3, the Skoda Octavia, and the Seat Toledo were built (Heikkilä et al. 2002); and the B-Zero project to build Peugeot 107, Toyota Aygo and Citroën C1 (Figure 1) in the same Toyota Peugeot Citroën Automobile plant (TPCA, 2007). Although platform sharing enables economies of scale and allows car companies to achieve cost-efficiency, the success of this strategy depend on sufficient differentiation between car models of different brands. If the perceived images of different car models become too similar, they may cannibalize each other’s market share, negating the advantages offered by platform sharing.

Figure 1: Peugeot 107, Toyota Aygo and Citroën C1 (Car Body Design 2004)

Faced with the task of differentiating car models based on a common platform, the task of a designer is twofold: at the brand level, the designer needs to continue and strengthen a specific brand image; and, at the individual model level, the designer seeks to create novel and distinct characters for a car model. The brand and model image can be manipulated by design via the use of visual elements (Bouchenoire, 2003; Karjalainen, 2007), which consists of design features to identify a brand and design features for specific models to emphasize individuality.

Several studies were reported in the literature on the systematic investigation of visual brand recognition. Karjalainen conducted several studies from 2004 to 2005 to investigate the semantic transformation from a brand character to visual design cues (Karjalainen, 2007). In (McCormack and Cagan, 2004), the method of shape grammar was employed to formulate the grammar rules that capture the Buick brand image. These rules were then applied to generate novel Buick designs for specific market segments. Using motorcycles as examples, a study was conducted by Kreuzbauer and Malter to test the effects of changes in product design elements on brand-category classification (Kreuzbauer and Malter, 2005).

Another related line of research on the visual aspects of product design involves the influence of the factors of typicality, novelty, and unity on aesthetic preferences. By changing design features to manipulate the levels of factors, positive effects of typicality and unity on aesthetic responses were reported in (Veryzer and Hutchinson, 1998). Testing Raymond Loewy's famous maxim of "most advanced yet acceptable," it was found that people prefer products with an optimal combination of both typicality and novelty (Hekkert et al., 2003).

Due to the limitation of available computer-aided tools, the above studies on brand recognition or aesthetic preferences were based on line drawings (McCormack and Cagan, 2004; Veryzer and Hutchinson, 1998), simplified black-and-white images (Kreuzbauer and Malter, 2005), photographs of existing products (Hekkert et al, 2003) and a limited number of computer renderings (Karjalainen, 2007). Detailed manipulations of design features were not possible. In addition, the degree of realism of product images was also constrained. Such limitations prevent more in-depth investigation on brand recognition and aesthetic preferences.

In this research, we developed a method for investigating the effects of design features on the perception of product designs, by combining a new computer tool for fast and realistic visualization of different feature compositions in designs, and the conjoint analysis method from marketing research for analyzing the individual effects. We then used the automobile styling design as an example to test the feasibility of the proposed method.

2. CONCEPTMORPH

ConceptMorph (Chen et al. 2006) is a computer-aided concept design system, developed by our research group, which enables a designer to rapidly explore a large number of product shapes. By using ConceptMorph, a designer can perform both product shape morphing and feature composition, and to specify or modify product shapes and features using free-hand sketches. New product shapes can be generated from either free-hand sketches, or synthesized from existing products that are successful in conveying the desired messages. At the feature level, the designer can easily add, remove, or replace features on product images, to obtain design variations. In addition to simply using features from existing products, the designer can hand-adjust features of a product while the system maintains the relationship between the feature and the rest of the product shape.

The ConceptMorph program was developed based on a novel image morphing technique that integrates image morphing with characteristic lines morphing (Wolberg,1990; Gomes, 1999). Every product shape P_i is represented by an image, I_i, and a set of characteristic lines, L_i, on the image. To obtain a new (destination) product shape P_d, we start by specifying the set of characteristic lines L_d that defines P_d. The transformation $W_{i,d}$ from P_i to P_d is computed from L_i and L_d, such that, when the image I_i is transformed by $W_{i,d}$, the set of characteristic lines L_i matches the set L_d. Using this scheme, it is possible to synthesize a new product shape P_d from any number of source product shapes, P_i, i = 1, …, n. The image I_d of the new product shape P_d can be computed as:

$$I_d = \sum_{i = 1,\cdots,n} W_{i,d} (I_i).$$

The set of characteristic lines L_d, which defines the new product shape P_d, can either be computed from L_i, i = 1, …, n, or be specified/modified interactively by designers. The latter enables designers to create new product shapes or modify features on a product by interactively drawing the characteristic lines.

Figure 2 shows the interface of ConceptMorph, where the left and middle windows display the characteristic lines (in blue) for the two source images, and the right window displays the weighted average of the characteristic lines (L_d, in green).

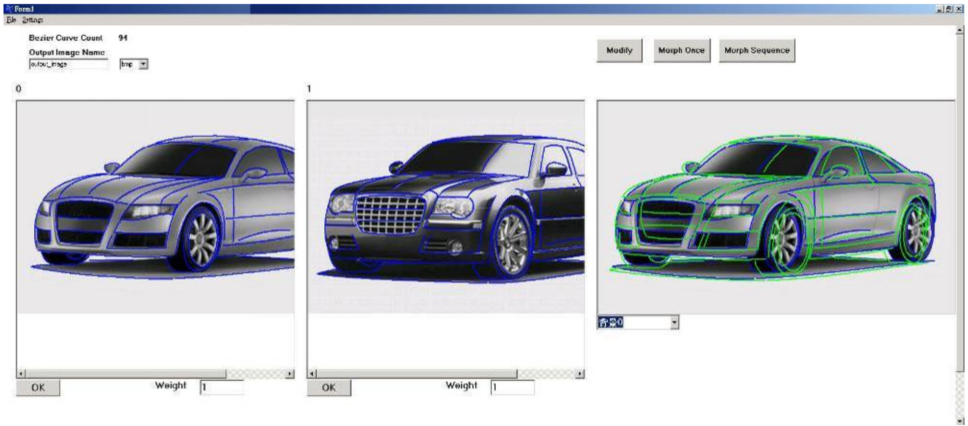

Figure 2: ConceptMorph: (Left and Middle) Characteristic Lines for Source Products; (Right) Weighted Average of Characteristic Lines.

3. CONJOINT ANALYSIS

Conjoint analysis is a method often applied in Marketing for measuring the joint effects of a set of product attributes on consumers' judgments (Green and Rao, 1971). An important special case of conjoint analysis is the additive model where it is assumed that a product can be specified by a combination of product attributes with discrete levels, and that the interactions among the product attributes are neglectable. From the consumer's overall judgments about product alternatives, the (additive) conjoint analysis method computes individual utility functions for the discrete levels of each attribute, such that the additive combinations of the utilities can be used to reconstruct the original overall judgments. The uncovered utility functions allow a researcher to understand the relative importance of each product attributes and the complex trade-offs performed by the consumers when making judgments about product alternatives.

In the literature, conjoint analysis has been applied to product concept testing during the design stage (Dahan and Srinivasan 2000), as well as to the affective design of mobile phones (Jiao et al. 2006). To investigate the effects of design features on the perception of automobile styling designs, we formulated each automobile design as a combination of important design features, and applied conjoint analysis to determine the utility function for each design feature.

4. STIMULUS DESIGN

Based on an automobile perceptual map (Chen et al. 2003), we selected a new automobile that is similar in its form to the automobile near the center in the perceptual map as the base automobile for the experiment, so that the automobile projects a fairly neutral image. To eliminate potential effects from non-form related factors, such as color and brand, we first cleaned up the image of the selected automobile by clearing the background, removing the brand logo emblem, converting the photograph to gray scale, and adding shadows below the automobile.

Four automobile design features – front grill, headlights, overall profile, and side vents – were selected for the investigation. To identify representative feature shapes, we collected 118 automobiles with distinctive design features. For each design feature, we selected the top two or three most frequently used shapes as levels for the experiment. This resulted in two different front grill shapes (rectangular, triangular), three different headlight shapes (round, triangular, rectangular), two overall profiles (smooth and angular), and two levels for side vents (with and without), as shown in Figure 3.

A. Front Grill	 A1: rectangular	 A2: triangular	
B. Headlights	 B1: rectangular	 B2: round	 B3: triangular
C. Overall Profile	 C1: angular	 C2: smooth	

D. Side Vents	 D1: with side vents	 D2: without side vents

Figure 3: Discrete Levels for Design Features

A full factorial design of these four features yields 2×3×2×2=24 combinations. Photorealistic visualizations of the 24 possible combinations of design features were generated by using ConceptMorph. Each automobile containing the desired feature was first distorted to fit the characteristic lines of the base automobile, and then the features were replaced to create the new automobile with the desired combination of design features.

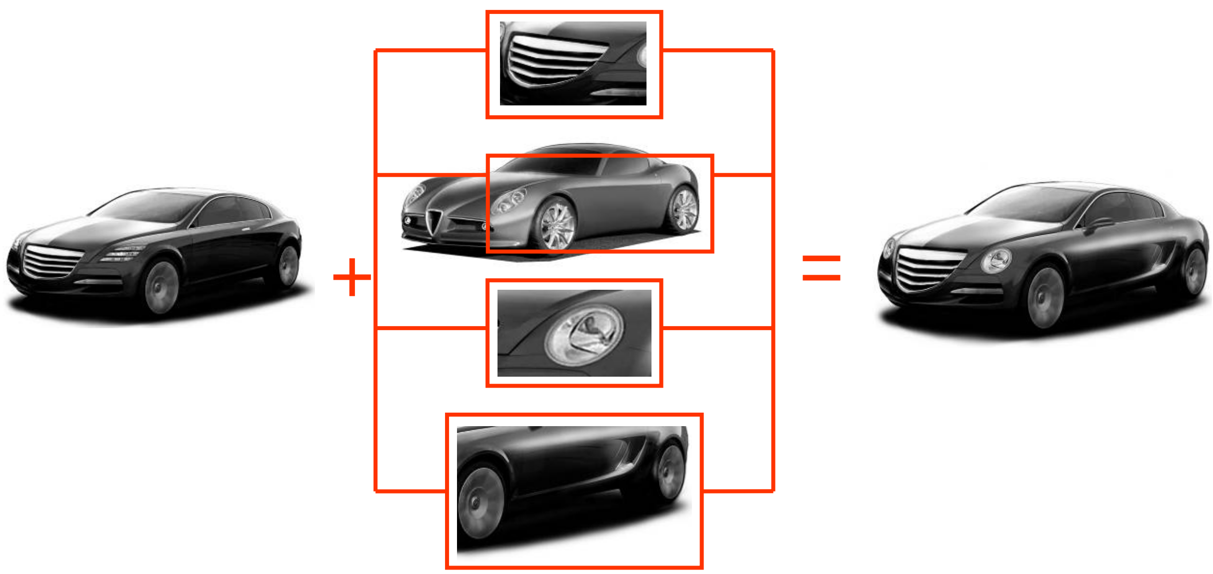

Figure 4: Photorealistic Visualization of Combinations of Design Features

5. EXPERIMENT

We conducted a survey on the affective responses to the 24 automobile styling designs by using 11 bipolar adjective pairs, which were identified in (Hsiao and Chen, 2006). These 11 adjective pairs are listed in Table 1.

Table 1: 11 Bipolar Adjective Pairs for Measuring Affective Responses to Automobile Designs

1. Static – Dynamic	2. Ordinary – Dazzling	3. Exaggerated–Truthful
4. Uncomfortable–Comfortable	5. Not Cute – Cute	6. Rough – Delicate
7. Rational – Emotional	8. Complex – Simple	9. Traditional – Contemporary
10. Immature – Mature	11. Weak – Strong	

Thirty subjects participated in the experiment. Half of the subjects are from design background; whereas the other half are not. Twelve of the subjects are female and the other eighteen are male. All subjects are between the ages of 19–28. The experiment was conducted using the Computer-Aided Kansei Engineering (CAKE) survey software (Chuang and Chen, 2003). The 24 stimuli were shown randomly on the computer screen. The subject then evaluated each stimulus with respect to each of the 11 adjective pairs by using a 9-point scale, e.g., extremely rational, very rational, quite rational, slightly rational, neutral, slightly emotional, quite emotional, very emotional, extremely emotional. The subject marked the level of the affective response according to his or her perception about the automobile design. Figure 5 shows the experimental setup.

Figure 5: Experimental Setup

6. RESULTS

We analyzed the judgment data on the 24 stimuli with respect to the 11 adjective pairs by using the conjoint analysis software in the SPSS Categories module. Using the adjective pair “Static-Dynamic” as example, the results from conjoint analysis are summarized in Table 2. The utility function for “Static-Dynamic” is:

Utility = A1（-0.3444）+ A2（0.3444）+ B1（-0.2014）+ B2（-0.3222）+ B3（0.5236）+ C1（0.3361）+ C2（-0.3361）+ D1（0.7528）+ D2（-0.7528）+ 5.3972

where, if the automobile contains a particular design attribute X then X = 1; otherwise, X = 0.

Table 2: Conjoint Analysis Results of "Static-Dynamic" Adjective Pair

Design Attribute	Importance (%)	Level		Utility
Front Grill	15.22%	A1	rectangular	-0.3444
		A2	triangular	0.3444
Headlights	28.20%	B1	rectangular	-0.2014
		B2	round	-0.3222
		B3	triangular	0.5236
Overall Profile	24.78%	C1	angular	0.3361
		C2	smooth	-0.3361
Side Vents	31.81%	D1	with	0.7528
		D2	without	-0.7528
Total (%)	100%	Constant		5.3972

Summarizing the conjoint analysis results for all adjective pairs, we obtained Table 3 about the relative importance of design factors on the perceptions of automobile style designs, with respect to each of the 11 adjective pairs. It can be observed that the adjective pairs "Static—Dynamic", "Ordinary－Dazzling", "Exaggerated－Truthful" and "Weak－Strong" were influenced mostly strongly by the existence of side vents and the shape of headlights. The adjective pairs "Uncomfortable－Comfortable" and "Complex－Simple" were influenced mostly strongly by the existence of side vents and the overall profile of the automobile. The adjective pairs "Traditional－Contemporary", "Immature－Mature" were influenced mostly strongly by the shape of headlights and the existence of side vents. Finally, adjective pairs "Not Cute－Cute", "Rational－Emotional" were influenced mostly strongly by the shape of headlights and the overall profile of the automobile.

Table 3: Relative Importance of Design Features on Perception of Automobile Designs

Adjective Pair	Most Important	Second Important	Third Important	Least Important
Static—Dynamic	Side Vents (31.81%)	Headlights (28.20%)	Overall Profile (24.78 %)	Front Grill (15.22 %)
Ordinary—Dazzling	Side Vents (36.35%)	Headlights (28.15%)	Overall Profile (22.10 %)	Front Grill (13.40 %)
Exaggerated—Truthful	Side Vents (47.19%)	Headlights (21.75%)	Overall Profile (18.59 %)	Front Grill (12.47 %)
Weak—Strong	Side Vents (31.52%)	Headlights (29.41 %)	Overall Profile (28.54%)	Front Grill (10.53%)
Uncomfortable—Comfortable	Side Vents (30.23%)	Overall Profile (28.78%)	Headlights (26.50 %)	Front Grill (14.50 %)
Complex—Simple	Side Vents (49.01%)	Overall Profile (21.59%)	Headlights (21.45 %)	Front Grill (7.95%)
Traditional—Contemporary	Headlights (35.64%)	Side Vents (31.07%)	Overall Profile (22.42 %)	Front Grill (10.86%)
Immature—Mature	Headlights (32.58%)	Side Vents (28.71%)	Overall Profile (23.30 %)	Front Grill (15.41%)
Not Cute—Cute	Headlights (54.79%)	Overall Profile (24.03%)	Side Vents (12.91 %)	Front Grill (8.27%)
Rational—Emotional	Headlights (33.73%)	Overall Profile (31.69 %)	Side Vents (24.61%)	Front Grill (9.98%)

For each pair of adjectives, we computed the utility functions to determine the automobile design with the two extreme images, and listed the corresponding set of design features.

Static—Dynamic (Figure 6)

Most dynamic ＝ triangular front grill + triangular headlights + angular profile + side vents

Most static ＝ rectangular front grill + round headlights + smooth profile + no side vents

Dynamic	Static
	

Figure 6

Ordinary－Dazzling (Figure 7)

Most ordinary ＝ rectangular front grill + round headlights + smooth profile + no side vents

Most dazzling ＝ triangular front grill + triangular headlights + angular profile + side vents

Ordinary	Dazzling
	

Figure 7

Exaggerated － Truthful (Figure 8)

Most exaggerated ＝triangular front grill + triangular headlights + angular profile + side vents

Most truthful ＝rectangular front grill + rectangular headlights + smooth profile + no side vents

Exaggerated	Truthful
	

Figure 8

Uncomfortable－Comfortable (Figure 9)

Most uncomfortable = triangular front grill + triangular headlights + angular profile + side vents

Most comfortable ＝rectangular front grill + round headlights + smooth profile + no side vents

Uncomfortable	Comfortable
	

Figure 9

Not Cute—**Cute** (Figure 10)

Least cute ＝ rectangular front grill + rectangular headlights + angular profile + side vents

Most cute ＝triangular front grill + round headlights + smooth profile + no side vents

Not Cute	Cute
	

Figure 10

Complex—**Simple** (Figure 11)

Most complex ＝ triangular front grill + triangular headlights + angular profile + side vents

Most simple ＝rectangular front grill + round headlights + smooth profile+ no side vents

Complex	Simple
	

Figure 11

Traditional－Contemporary (Figure 12)

Most traditional ＝ rectangular front grill + rectangular headlights +smooth profile + no side vents

Most contemporary ＝ triangular front grill + triangular headlights + angular profile + side vents

Traditional	Contemporary
	

Figure 12

Immature－Mature (Figure 13)

Most immature ＝ triangular front grill + round headlights + smooth profile + side grill

Most mature ＝rectangular front grill + rectangular headlights + angular profile + no side grill

Immature	Mature
	

Figure 13

Rational－Emotional (Figure 14)

Most rational ＝rectangular front grill + rectangular headlights + angular profile + side grill

Most emotional ＝triangular front grill + round headlights + smooth profile + no side vents

Rational	Emotional
	

Figure 14

Weak－Strong (Figure 15)

Weakest ＝ rectangular front grill + round headlights + smooth profile + no side vents

Strongest ＝triangular front grill + triangular headlights + angular profile + side vents

Weakest	Strongest
	

Figure 15

7. CONCLUSIONS

In this paper, we reported a method for evaluating the effects of design features on the perception of product designs, by using ConceptMorph software for fast and realistic visualization of different combinations of design features, and by applying Conjoint Analysis for computing the utility functions for the design features.

We used automobile styling design as an example to evaluate the feasibility of the proposed method. We selected four automobile design features – front grill, headlights, overall profile, and side vents – for investigation. By using conjoint analysis, we computed the relative importance of each design feature on the perception of automobile design, with respect to 11 adjective pairs for measuring affective responses. We also provided visualizations of the automobile designs that elicit the strongest/weakest responses with respect to each adjective pair. These results provide detailed information about how to manipulate design features to achieve specific affective responses.

Finally, we would like to add a cautionary note about applying the method proposed in this research to product design. The method focuses on the detail design at the feature levels, which should be towards the end of the design process, when the overall shape and character of the product has been defined. At that stage, designers could apply this method to fine tune the image projected by the product, by trying out different combinations of design features from existing products, or from designers' own creations. However, compositions of design features do not constitute a complete design process. To design a successful product, designers must pay attention to the design of the whole product, not just to the features.

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