CHARACTERIZING AND EVALUATING AESTHETIC FEATURES IN VEHICLE DESIGN

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The design and development of vehicles requires large investment compared with most mass produced products. Consequently there is a large financial risk associated with the commitment to develop and produce new vehicles. It is also known that aesthetics have a major influence on a vehicle's desirability and subsequent commercial success. Similarly, brand perception of the vehicle manufacturer greatly influences desirability and judgments of quality and is shown to be closely linked to aesthetic features. Some attributes of potential vehicle designs such as fuel economy or performance, can be evaluated quantitatively and thus superior designs easily identified. In contrast aesthetic features and their subsequent impact on brand perception are subjective and thus much harder to evaluate. Currently such evaluations are based on designers' previous experience and intuition. This paper presents a preliminary study that explores the creation of a tool aiming to help designers to evaluate aesthetic features of vehicles and reveals that certain aesthetic features have a greater impact on consumer response to designs than others.

Keywords: Aesthetics, Features, Vehicle Design, Research Methodology.

1. INTRODUCTION

The complex nature of vehicles compared with other mass produced products, along with lengthy design and development times require considerable investment from manufacturers. With this investment comes considerable financial risk relating to the success or failure of vehicles when launched onto the market.

It is known that aesthetics play an important role in the successful consumption of products [1–3]. Audi states that up to 60% of a consumer's decision to purchase a vehicle is based on its product design [4]. In the same way that aesthetics can influence consumer judgment so can brand. Perceptions of the brand of a product influence judgments on a product's quality and its overall desirability and are mostly derived from the product's appearance [1, 3]. Consequently, aesthetics are one of, if not the most important factors in vehicle design. Despite this, evaluation of the aesthetic qualities of a vehicle's design is still based on designer's previous experience and training, and the notion of designer's intuition.

Bearing these factors in mind, this paper sets out to explore the creation of a tool to aid designer's judgments when evaluating potential vehicle designs. The paper begins by discussing the background to the process of vehicle design and the role of aesthetics and branding in a product's design (Sec. 2). This background contextualizes the principle aim of the work (Sec. 3) which then defines the objectives of the investigation reported in this paper. Section 4 includes a review of previous related work. The methodology for this investigation is set out along with the results (Secs. 5 and 6 respectively). Results are then discussed (Sec. 7) and conclusions drawn in Sec. 8.

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2. BACKGROUND

As the main focus of this study the aesthetic features of a vehicle's design, only those stages in vehicle development where aesthetics are discussed by designers are considered. This is not to say that aesthetics are neglected throughout the remaining stages of a vehicle development, rather this is the stage where the aesthetic design is generated and evaluated.

2.1. Vehicle Styling Process

The aesthetic features of a vehicle exterior are commonly referred to as 'vehicle styling'. To better contextualize the sphere in which this research is being conducted, the process by which 'vehicle styling' is generated is presented (Figure 1).

The steps set out in Figure 1 are based on information gathered from industry representatives and practicing 'stylists'. It is acknowledged that different manufacturers may adopt slightly different processes, however, the steps set out in Figure 1 represent the activities undertaken by the vast majority of design teams. In particular design teams receive information from marketing and product planning departments outlining basic requirements of the design. Designers then work to develop concepts with low levels of detail into a final proposal realized in the form of a full scale clay model. Throughout the styling process (Figure 1) there may be a number of iterations of design proposals. While these iterations prolong the styling process, and increase development costs, they are necessary in developing and converging the design.

By generating and evaluating a number of concepts, design teams develop the design of a vehicle exterior, and thus its aesthetic features that are so crucial for commercial success. The process through which a vehicle's aesthetic is created has been discussed along with the importance of aesthetics. However the mechanisms behind aesthetics and the concept of brand should next be considered.

2.2. Aesthetics and Brand in Product Appearance

Aesthetics are the primary influence on the way consumers judge a product [3]. For almost every product purchased, the consumer's first contact with it is visual. Hence a product's appearance is of great importance to designers and manufacturers [1]. Bloch [1] also outlines the main functions of aesthetic features in the market. Aesthetic features can help products to stand out among other competing products on the market therefore increasing popularity and market share. This function of aesthetic features becomes increasingly important in industries, such as the automotive industry, where manufacturers can rely less on novel or innovative technological features to make their products stand out among competitors [5].

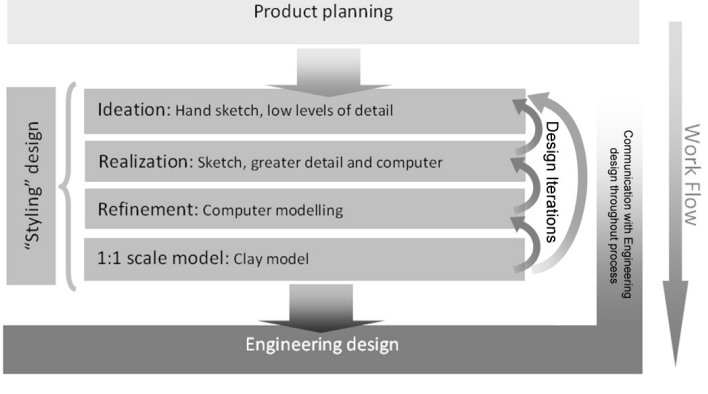

Figure 1. Vehicle styling design process.

The second key function of product aesthetics is to communicate the mode of operation to user as well as the manufacturer's/brand's values [6, 7]. In other words the perception the branding of a product is derived from aesthetic features. Van Rompay *et al*. [8] concur with this view stating that when lacking other sources of product information, evaluations of brand are based on product appearance. Since brand perception forms a major part of the perceived quality of a product [1], it can be said that aesthetic features heavily influence the perception of quality.

The relationship between aesthetic features and brand presents a compromise in that aesthetic features must be distinctive such that new products stand out from their predecessors and competing products, but must also be familiar enough such that brand can be positively identified. Moulson and Sproles [2] consider this compromise made by designers between progressive designs that standout and less revolutionary designs that are easy to identify. A misjudged compromise risks damaging heritage as the design may be poorly received, or well received but by the wrong market segment.

The various functions and influences of aesthetic features on consumer response to products are complex. As a result the evaluation of such aesthetic features requires designers to consider a number of conflicting factors. This consideration is made even more complex by the subjective nature of aesthetic features. In the case of aesthetic features, compromises must be judged based on design managers' previous experience and instinct. It is the evaluation and judgments of aesthetic features that the principle focus of this research. In particular, the overreaching aim is to create a tool to characterize and measure aesthetic features in order to aid designers and managers by providing further insight when evaluating such features. Provision of greater insight will in turn reduce risks in launching new designs and reduce development costs by reducing the number of iterations, or time taken to iterate within the styling process. This paper reports the research carried out to address the first objective in achieving the aim. In order to be able to measure and characterize aesthetic features, two primary objectives are explored in this work; To propose a strategy to identify and extract aesthetic features, and to understand relationships between individual features and consumer perceptions.

3. DECOMPOSITION AND EXTRACTION OF AESTHETIC FEATURES

Over the past two decades significant research has been conducted relating to the subject of decomposition and extraction of design features. This section highlights relevant studies describing the methods used and their application.

Biederman [9] approached this topic from a cognitive psychology standpoint, investigating the effect of different constituent features in simple illustrations of commonplace objects. A series of experiments was conducted where participants were asked if they could recognize the different objects when 'degraded' to different levels. Biederman degraded images by removing lines and corners/angles in different proportions of the overall image. The findings showed that participants in the first instance could recognize degraded or incomplete objects. The study also found that certain constituent lines/features encourage better recognition than others. The significance of Biederman's study is that it demonstrates the principle of decomposing images and isolating constituent parts in order to further investigate their effect on recognition.

More closely related to the study of this study, is the work of Cheutet et al. [10] studying "aesthetic key lines". These were defined as lines on a vehicle surface that were thought to be aesthetically important on vehicles. The aim of the study was to help preserve the original design intent through the complete vehicle design process. Previous work defined curve geometries in the terminology used by stylists. Vehicles front, side and rear views were decomposed into the aesthetic key lines and their aesthetic properties were reviewed. Data was used to create an ontology of curves linking quantitative properties from digital models with aesthetic properties based on stylists' terminology. The key relevance of this study to the work reported here is the identification, extraction and representation of aesthetic features of vehicles.

The works of McCormack *et al*. [11] in shape grammars also decompose images and extract aesthetic features. In order for it to be feasible for a shape grammar to generate car and motorcycle concepts, the parts and aesthetic features were simplified to two dimensional line representations. Shape grammars

were then used to generate a range of concepts experimenting with aesthetic features and recognition of brand. This research shows that simple 2d line representations of vehicles can still contain enough visual information to portray some degree of aesthetic characteristics.

Related to the current study is work by Tovey and Porter [12], considering sketching in automotive design and the technique of 'de-layering' to decompose drawings. The de-layering process consists of taking sketches made by students and professionals and breaking them down into form lines, components, form shading and non-form shading. The study showed the form lines to be most expressive and carry the intentions of the designer. The study further showed that certain features may be isolated as containing the major aesthetic characteristics of a design.

Warell [13] investigated 'form-syntactics'. These are all features characterizing the aesthetic effect of visual form. The approach adopted to achieve this began with the identification of these syntactics. In order to investigate them further, a syntactic analysis was conducted in which consumers were shown images of the same product where syntactic elements were either altered or excluded. Participants were surveyed as to how well different adjectives characterized the variant designs. Conclusions drawn from this study suggest that by using this approach it is possible to gather valuable information on the effects of particular aesthetic features.

Karjalainen [14] conducted a similar study in which product ranges were decomposed and features identified as being characteristic of particular brands were isolated. These features were then used as a basis for designing different products but still identifiably of the same brand. Results showed that such analysis of the product range and isolation of features could be used as a basis to design products exhibiting distinct brand features.

While all of these studies are relevant in their demonstrations of strategies for decomposing and isolating aesthetic features, no single method is entirely suited for the current study. All of the strategies reviewed, with the exception of Warell [13], are concerned with the generation and development of new designs rather than analysis of existing vehicles. Strategy presented by Warell [13] does analyze existing vehicles, but with respect to perceived character through aesthetics, rather than brand identity. Consequently elements from a number of the studies are adapted to develop the decomposition method used here.

4. METHOD

As stated in Sec. 2, the key objectives of this investigation are to propose a strategy to decompose vehicle designs isolating aesthetic features and then begin to characterize them. In order to achieve decomposition and extraction of features, the following strategy is proposed. The strategy draws on studies discussed in section 3, as well as information gathered from practicing designers to first define what constitutes an aesthetic feature.

Cheutet *et al*. [10] and McCormack *et al*. [11] both identify 'character lines' within a vehicle's body work highlighting their contribution to overall vehicle aesthetic, and represent these using curves. Warell [13] makes particular reference to 'graphic' features of vehicle design such as headlights, logos and grill elements. These identifications were also corroborated during interviews with industry. Discussions on the vehicle styling process highlighted four main types of aesthetic feature addressed when creating design concepts/proposals; 'Outline' also be described as the vehicle silhouette, 'Daylight opening' (DLO), this constitutes the front and rear windshields and side windows, 'Muscles' which are treatments applied to body work, usually in the form of raised or lowered creases or sections, and 'Graphics' as previously defined.

These four feature types form the feature categories into which designs are decomposed and isolated. The application and mapping of each of these categories to the front, side and rear views of a vehicle is illustrated in Figure 2. The mapping was achieved by tracing features from vehicle photographs using B-Spline curves. In front and rear views, the manufacturer logos were removed from the graphic category to form a further fifth feature category, explicit detail. This was done as the logos were thought to be overly explicit in identifying vehicle brand.

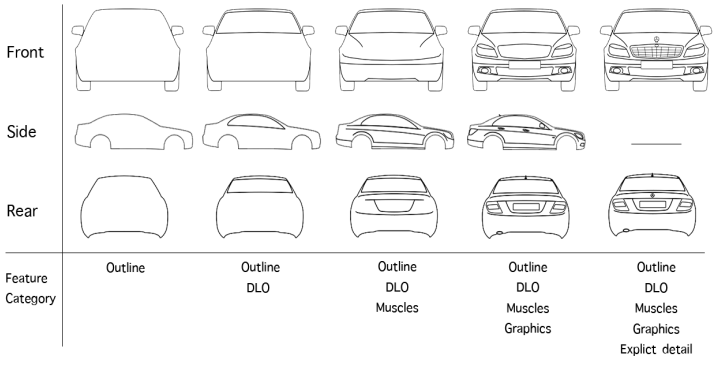

Figure 2. Feature decomposition and extraction strategy.

The mode of representation of the vehicles and constituent feature categories draws on those used by Biederman [9], Pugliese and Cagan [15] and McCormack *et al*. [11]. Vehicles and constituent features shall be represented by 2d line illustrations (Figure 2).

The decomposition and extraction strategy illustrated in Figure 2 was applied to five different saloon vehicles: Audi A4, BMW 3 Series, Ford Mondeo, Honda Accord and Mercedes-Benz C-Class.

These vehicles were selected as they are said to be in competition in the same vehicle segment/class and price range and are considered to be of recognizable brand. In order to characterize and evaluate these aesthetic features and their relationship with consumer perception, a survey was undertaken in which participants were asked to respond to features and evaluate them. During this study, participants were asked to characterize images, and thus aesthetic features, by vehicle segment, character and brand. Due to the preliminary nature of the investigation and the high degree of abstraction in images, it was thought that it was appropriate only to survey consumer identification of different visual characteristics rather than the degree to which features embody the characteristics. Thus participants were asked the following three questions in response to images by selecting one answer from a list of options: 'In which segment does this vehicle belong?' 'Which emotions best describe this vehicle's character?' 'Which brand manufactures this car?'

A sequence of images, including 10 front views, 9 side views and 9 rear views which comprise an increasing number of features, was presented to participants with the three questions posed in reference to each image. The combination of images was selected in order to show most of the decomposition combinations for a variety of vehicles while avoiding explicit vehicle identification too early in the survey. Participants were given limited time to answer each question. This was intended to encourage participants to record their initial perceptions and to shorten survey time.

In addition to the main survey, participants were asked to complete a profiling section. The aim of this was to gather basic information on participants such as age and gender, their use (exposure) to cars and self assessed confidence in knowledge of cars.

5. RESULTS

The survey was made available online for five days. A total of 420 responses were recorded. Respondents were aged between 17 and 63 years old. 78% of responses were recorded by male participants and 22% by female. Participant profiling showed 49% of participants held a car's styling as being 'very important' when considering purchasing a car while 43% responded 'mildly important' and 8% responded 'not important'. It was also found that 36% of participants held vehicle brand as being 'very important' when considering purchasing a car, while 50% responded 'mildly important' with 14% responded 'not important'. Participants were surveyed on their confidence in their ability to identify vehicle brands. From the vehicles included in the survey, participants were most confident

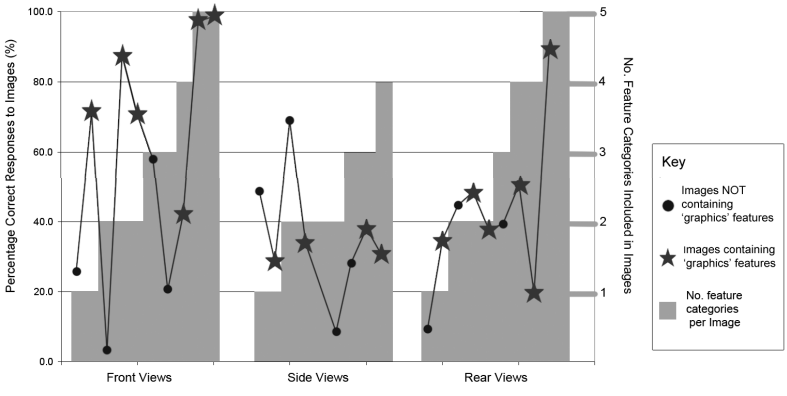

Figure 3. Demonstrating the percentage of correct identifications of brand, with respect to images shown and the number of feature categories included within images.

in their ability to identify BMW, with Mercedes second, Audi third, Ford fourth and Honda with the least confidence.

For the purposes of reviewing participants' ability to correctly identify brand, responses have been broken down into categories such that they can be defined as 'correct' or 'incorrect'. Criteria for correct and incorrect responses were based on manufacture's literature on the respective vehicles. Results are illustrated in Figure 3.

6. DISCUSSION

The purpose of conducting this survey was to investigate the proposed strategy for decomposing and extracting aesthetic features in order to characterize and evaluate their relationship with consumer perception. When first viewing the results (Figure 3) it is clear that different isolations of feature categories elicit different levels of response from participants. Thus it can be seen that despite the relatively high level of abstraction of images shown to participants, the aesthetic features that constitute images are still rich enough to elicit a range of responses.

It should also be noted that participants achieve far more correct responses to questions relating to images of front views. The average percentage of correct response to front view is 58%, while the average percentage of correct response to both side and rear views is 41%, illustrated in Figure 3. This suggests that aesthetic features in the front view are more dominant, particularly in response to vehicle brand. This implies that aesthetic features on the front of vehicles have a greater influence on consumer's ability to identify them.

As participants progressed through each part of the survey (front, side and rear) a higher number of features were included in images. Surprisingly it can be seen in Figure 3 that some images containing fewer features were recognized by a greater number of participants than images containing many feature categories. A chitest shows that the percentage of correct responses is independent of the number of feature categories included in images. Values for X^2 were found to converge to zero in front, side and rear cases. Hence, it can be said that certain feature categories have greater influence over the consumers' ability to identify vehicle characteristics than other feature categories.

When the images scoring high percentages of correct response are examined in closer detail, it can be seen that many include the 'graphics' category of features (demonstrated in Figure 3). This would suggest that the 'Graphics' feature category in the front view is the most potent aesthetic feature for brand recognition.

Throughout the survey participants achieve less correct responses to questions on segment and character than to questions on brand. The average proportion of participants answering questions correctly was 33% for questions on segment, 30% for questions on character, and 45% for questions on brand. It is thought that verbalizing a vehicle's emotional character was found by participants to

be difficult, especially in reference to the low detail images. This could be tested and improved by repeating the survey using images with greater detail. The majority of responses (average 33% correct) to vehicle segment were also incorrect. This was especially surprising for side views as it was thought that the vehicle outline and DLO would clearly indicate the segment. It is thought that the explanation for these results is that the terminology used to define segment, although technically correct (based on EuroNCAP classification [16]), were somewhat ambiguous to interpret. Further experimentation asking participants to identify segment pictorially is suggested to remove this ambiguity.

A multivariate analysis of results was conducted including information gathered in the profiling stage of the survey. This was done to ascertain whether the effect of participant's prior knowledge of, and exposure to vehicles had any effect on participant's ability to identify vehicle characteristics. Broadly, of the participants correctly identifying vehicle characteristics, the proportions of age, gender, confidence in identifying brands and interest in styling reflected those of the total participant sample. As would be expected, it was found that participants who could drive and spent longer per week on the road answered a greater proportion (5%) of questions correctly than those who did not.

7. CONCLUSIONS

Aesthetic features have been highlighted as a one the influential factors leading to a successful product. A web-based survey was devised to investigate the decomposition and extraction of vehicles' aesthetic features in order to further characterize and evaluate their influence on consumer perceptions. Following this investigation it is possible to draw a number of conclusions. Firstly, it can be concluded that the method for decomposing and isolating aesthetic features demonstrates that some features are more characteristic of vehicle brand than others. Graphic aesthetic features such as head lights, grill, and air intake are most potent in characterizing vehicle brand. Finally, the emergence of certain feature categories being most characteristic of vehicle brand further reinforces the need for exceptional consideration of certain features during evaluation of vehicle styling.

Having decomposed and isolated broad groups of aesthetic features, further work is planned to isolate and investigate graphic features in greater detail. This will be achieved through research into possible metric by which to measure features as well as gathering further data to characterize them in greater detail. By accomplishing this it is expected that a quantitative evaluation tool could be created to provide designers with further insight into aesthetics when designing vehicles.

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