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COMPUTER-GENERATED CARS YOU HAVE TO LOVE: HOW IMAGE MORPHING AND WARPING HELP DESIGNERS TO OPTIMIZE THEIR DESIGN SKETCHES

Completed Research Paper

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Abstract

Although product design is considered as a core determinant of a product's market success, systematic approaches that allow managers to increase a product's visual attractiveness are not available. The present research addresses this gap by adapting an approach that was originally developed in research on human facial attractiveness to a product design context. In particular, we propose that image morphing and warping techniques can be used to identify and manipulate those design features that drive a product's perceived attractiveness. Moreover, we also develop a computer-assisted interface that allows consumers to individually determine their optimal car design. Three studies with real consumers focusing on the automotive market confirm the viability and the usefulness of our approach. From a managerial perspective, the approach may increase the effectiveness of design efforts and may help in integrating consumers' preferences in an early stage of the product design process.

Keywords: Image Morphing, Image Warping, Car Design, User-Centered Design Optimization, Method-of-Adjustment, Experimental Design

Introduction

The aesthetic appearance of a product may be an important source of competitive advantage. For instance, managers at the German car manufacturer Audi estimate that up to 60% of a consumer's decision to buy a particular car is determined by the aesthetic appeal of the car's design (Kreuzbauer and Malter 2005). However, design is not only of relevance from a managerial perspective, but has also captured the attention of academic scholars (Bloch 1995; Landwehr et al. 2009). As Bloch (1995) notes, product design may not only serve to fulfill consumers' aesthetic needs, but may also create an initial impression of the product that serves as a basis for evaluating a product's more functional and utilitarian features. For instance, consumers may infer that a product that is aesthetically attractive is also superior from a functional perspective. This process is known as the "what is beautiful is good" heuristic and has been shown to influence impressions in a wide variety of contexts (Dion et al. 1972). As such, managers need to be aware that a product's shape, material, proportion, color, and texture may exert a significant impact on consumers' aesthetic and functional judgments, as a result of which design-related decisions may be crucial for a product's success in the marketplace. In this respect, Just and Salvador (2003) have also suggested the need for a brand compass to guide design efforts, ensuring that any particular design element is consistent with consumers' needs and preferences.

In contrast to this unanimous consensus among practitioners and academics about the importance of design, the current literature has not yet developed a systematic approach for enhancing the visual attractiveness of a product's appearance. That is, there is no approach that would systematically support designers and managers in giving their products an appearance that pleases the eyes of consumers. So far, most approaches have followed the opposite route by testing to what extent a given design is able to delight a selected group of lead customers (cf. Michalek et al. 2005; Demirtas et al. 2009). That is, consumers are usually exposed to a design prototype and are then asked to indicate to what extent the prototype fulfills their aesthetic expectations. Such approaches usually rely on conjoint analyses (cf. Huertas-Garcia and Consolación-Segura 2009; Silayoi and Speece 2005). However, these approaches may require several iterations to uncover an optimal design solution and may therefore not be very cost-effective. From a managerial perspective, it would be more useful to identify an approach that would provide designers with a guideline for their creative work and would allow them to focus on critical design features that are directly linked to consumers' aesthetic experience.

The purpose of the present research is to address this critical gap in the literature by adapting a methodological approach that was originally developed in research on facial attractiveness. The rest of this paper is structured as follows. Firstly, we provide a brief review of psychological theories of aesthetic attractiveness, which are useful for understanding when and why product designs elicit positive aesthetic reactions. Secondly, based on this literature review, we introduce image morphing and image warping as techniques that managers and designers may use to systematically enhance the attractiveness of their products. Thirdly, we report the results of three studies that focus on the automotive market and examine how the design of a car's frontal and lateral appearance can be optimized in order to maximize the aesthetic experience of the beholder. The first study is exploratory in nature and identifies those design features that are most suitable for improving a car's visual attractiveness. The second study is confirmatory in nature and is intended to validate the proposed approach with a large consumer panel by exposing them to experimentally manipulated car images that have been optimized according to the dimensions identified in the first study. The third study is aimed at further validating the morphing and warping procedures employed in the first two studies and at producing more fine-grained implications regarding optimal product designs. Furthermore, by employing a computer-assisted interactive user-interface, the study points to a potential application of such techniques in the context of mass-customized products. Finally, we conclude by critically discussing the implications and limitations of our method.

Identifying Systematic Determinants of Beauty

The question of what makes an object aesthetically appealing is an old and intensively debated topic in the psychological literature, dating back to the groundbreaking studies from Gustav Theodor Fechner (1876) - the founding father of experimental aesthetics. Aesthetics received widespread scholarly attention in the 1970s when Berlyne (1974) redefined the field with his new experimental aesthetics and has only recently reemerged as an important topic for research. More specifically, recent research has examined aesthetics from the perspective of processing fluency - an increasingly popular theoretical framework in many research contexts (cf. Reber et al. 2004).

The core proposition of the fluency framework is that when people process a given stimulus, they form a meta-cognitive processing experience; that is, they monitor how difficult it is to process the stimulus. Research in this area has shown that easy or fluent processing is an intrinsically positive experience that elicits positive affect (for an overview, see Reber et al. 1998). The positive affect elicited by fluent processing is, in turn, attributed to the stimulus, such that fluent stimuli are typically evaluated more favorably. Importantly, the fluency experience is often determined by some core characteristics of the stimulus, such as the stimulus' prototypicality (Winkielman et al. 2006). That is, stimuli that are very typical of their category can be processed more easily, thereby eliciting higher feelings of fluency and more positive aesthetic evaluations. From this perspective, a car that has a design that is very common within its particular category should be evaluated more favorably. In accordance with this notion, researchers in the field of human facial attractiveness have found that a morphed face (i.e., the visual "mean" of several individual faces) is a close approximation of a viewer's mental prototype and is rated as more attractive than the individual faces it is built from (Langlois and Roggman 1990).

Although many studies have attested to the validity of the fluency account, there are several important issues that remain unresolved. First, while fluent stimuli may initially elicit favorable reactions, people may also experience feelings of boredom when a stimulus is too easy to process and does not challenge them (cf. Berlyne 1974; Mandler 1982). As such, Meyers-Levy and Tybout (1989) have suggested that there is an inverted u-shaped relationship between prototypicality and aesthetic liking. That is, people frequently prefer stimuli that are somewhat different from the category prototype rather than stimuli that are very close to the prototype or very different from it. Second, in support of this reasoning, studies have found that people only transfer the positive affect elicited by fluency to their evaluations of the stimulus when other stimulus characteristics add complexity to the perception and make the fluency experience come as a surprise (Bornstein and D'Agostino 1994; Landwehr et al. 2009). Hence, these findings suggest that product designs that are somewhat different from the category prototype may receive the most favorable reactions. One limitation of these studies is, however, that they only suggest that product designs should be different, but do not provide any indications as to *how* exactly a design should differ from the prototype.

In contrast, research on facial attractiveness provides more specific directions in this respect. For instance, rather than postulating that people will favor any stimulus that is moderately different from the prototype, Perret et al. (1994) argue that people only prefer very specific deviations from the prototype. Changes in terms of the shape and the proportions of a prototypical face are only evaluated more favorably as long as they allow the beholder to make cognitive inferences about the face's more abstract characteristics, such as its perceived honesty and friendliness (cf. Corneille et al. 2004; Herba et al. 2007; Ji et al. 2004). These findings may also be of relevance in the context of product design, especially for the design of cars. That is, since the perception of human faces and the perception of cars share many similarities (Aggarwal and McGill 2007; Miesler et al. 2010), one may expect to find similar preference patterns for cars. More specifically, applying the findings of facial attractiveness research to a product design context may yield two important implications. Firstly, one may argue that cars also convey specific meanings through particular shapes and proportions and that these meanings may be conveyed more effectively by accentuating these shapes and proportions. Hence, managers may need to uncover those deviations from the prototype that are most influential in driving aesthetic liking. Secondly, one may also argue that deviations in terms of shape and proportions may only increase aesthetic liking up to a certain point, after which the product design becomes too atypical of the category and the fluency experience decreases again. Hence, one would expect to observe an inverted u-shaped pattern between systematic prototype deviation and liking, mirroring the findings of facial attractiveness research. Since the main goal of this research is to examine whether the findings of facial attractiveness research can be applied to a product design context, it seemed advisable to rely on the methodological techniques that are established in that field of research, namely image morphing and image warping. Next, we provide a brief discussion of these two techniques.

Image Morphing

Morphing refers to a method for building an archetypical facial image out of a number of individual faces. In other words, morphing consists of blending several faces into an average face (Benson and Perrett 1993; Steyvers 1999). To create a morph, one first needs a number of images of a certain genre (e.g., a series of faces) that depict the same characteristic features and that have been generated under the same conditions. In a next step, one must define a number of feature points that are common to all of the stimuli. In general, the feature points should be those aspects of the stimuli that have a significant effect on the visual experience. For example, the position of the eyes, nose, and lips usually constitute the feature points of human faces. Figure 1a depicts a face on which 34 different feature

points have been applied. Following the definition of the feature points, a software then calculates the mean position of each feature point across all faces. The original images are subsequently distorted to these average proportions, such that images with identical proportions but individually varying color information are generated. Finally, the color values for each pixel are set to their average values across all images (cf. Wolberg 1994; for all reported morphing and warping applications the gtk-morph software environment by A. C. G. Mennucci was used). The image created through this process is a morph that is effectively an average of all the individual faces. Figure 1b shows an example of a morph, which was created from 20 male faces photographed under standardized conditions.

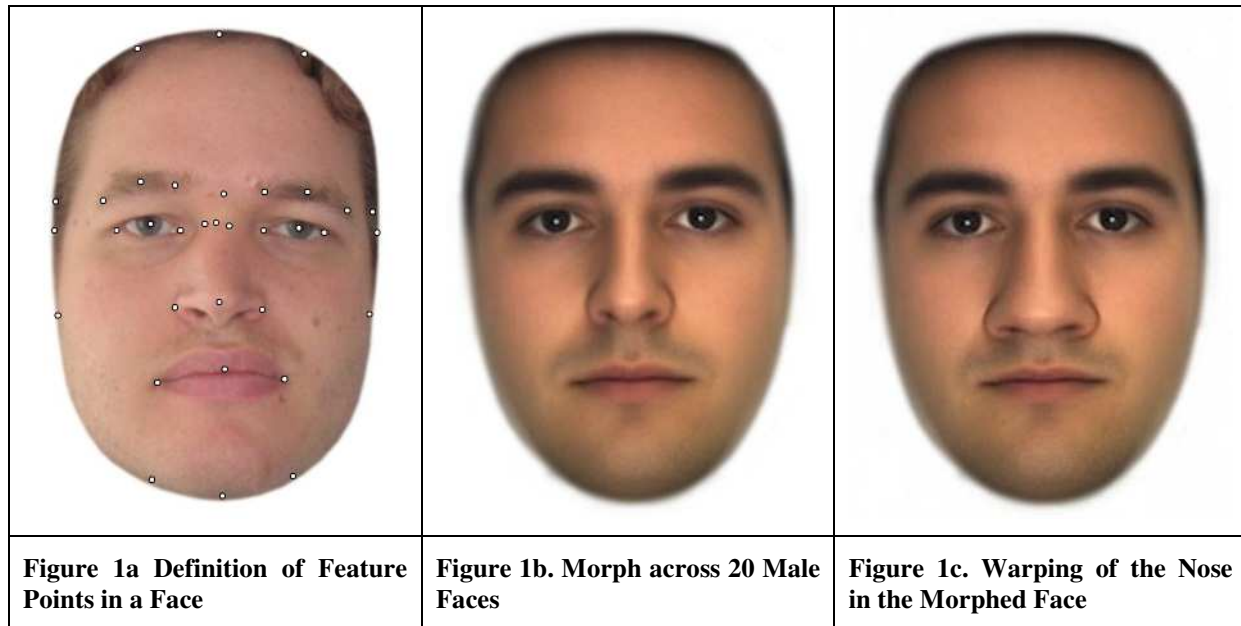


Image Warping

Image warping, in turn, refers to a method through which the proportions of an image (e.g., a human face) can be manipulated in a specific manner (Benson and Perrett 1993). The procedure is based on shifting specific feature points in order to intensify a given impression. Figure 1c shows a warp that is based on the morph presented in Figure 1b and that was created by shifting the feature points situated around the nose in different directions.

The purpose of this procedure can be easily demonstrated through an example. For instance, imagine that one is interested in identifying those elements of a face that make it appear particularly attractive. To this end, participants are typically asked to rate, say, 20 different photographs of human faces in terms of their attractiveness. However, these ratings do not allow one to determine why some faces are more attractive than others and to identify those features that determine attractiveness. Each face usually features a number of unique elements, and most individuals are not capable of reliably stating the significance of each element. To address this issue, it appears sensible to combine a certain number of faces from the top, middle, and bottom of the ranking into different morphs. By means of this procedure, three new, average faces are obtained that lack any unique elements and that vary systematically in terms of their attractiveness.

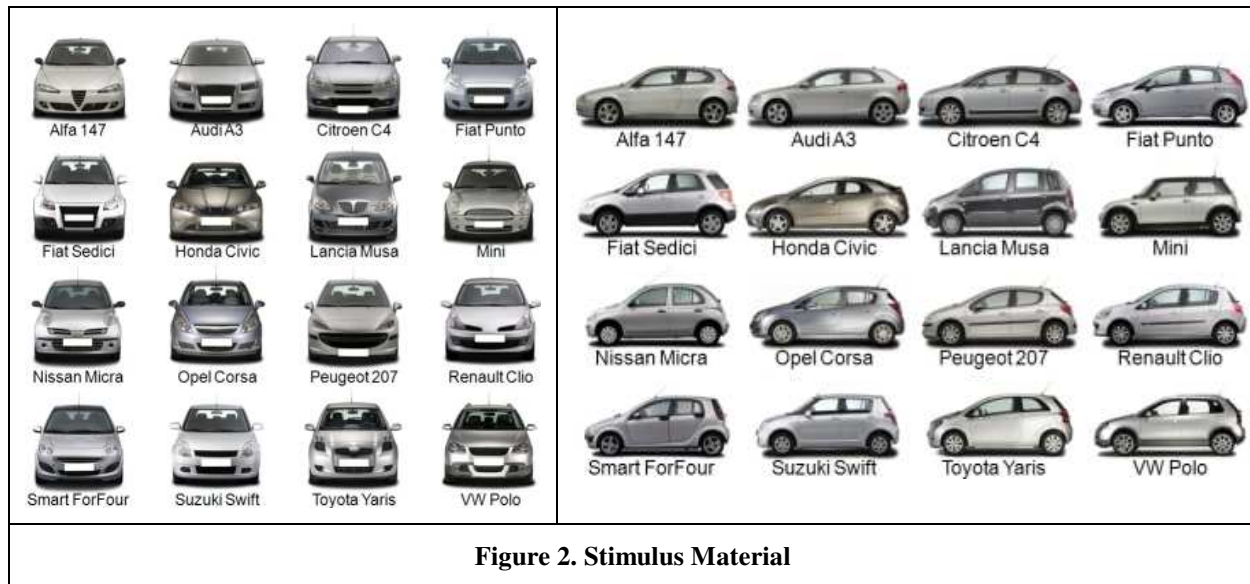
Furthermore, by comparing the position of the feature points across the three morphs, it becomes possible to identify those features that differ across the images and that determine attractiveness (cf. Perrett et al. 1994). Subsequently, the differences between the attractive and the unattractive morph may be accentuated by "warping" the images. To this end, the feature points where the attractive and the unattractive morph differ most strongly are shifted in the direction of increasing or decreasing attractiveness. Thus, it becomes possible to manipulate the attractiveness of a face in a controlled manner. Importantly, the application of image morphing and warping techniques is in principle not limited to a certain class of stimuli, such as faces, or to a certain evaluative dimension, such as attractiveness.

Empirical Study

In the empirical part of the paper, we applied image morphing and image warping techniques to examine whether judgments of beauty can be traced back to specific design features and their relation to each other. Furthermore, we also investigate if it is possible to create products that differ in terms of their aesthetic appeal by systematically varying the appearance of these design features. We chose to focus on cars since product design is an important driver of consumers' purchase decisions in this industry (Landwehr et al. 2009). Hence, the car industry is a particularly interesting context to examine the optimization of product design by means of computer-assisted image manipulations. The objective of the empirical study was to reveal those features in a car's appearance that systematically determine its attractiveness. To this end, we followed three steps. Firstly, a sample of consumers evaluated the design attractiveness of each of the 16 original vehicles (study 1). Secondly, we experimentally developed three separate morphed cars that consisted of the most attractive, the least attractive and the average designs. To test the validity of our approach, we collected confirmatory attractiveness ratings of these cars (study 2). Finally, in order to determine how certain design features/feature points must change to produce maximal perceptions of attractiveness, we also developed an interactive graphics tools that allowed participants to modify the shape of a car in a systematic manner (study 3).

Stimulus Material

Since it would have been unfeasible to conduct an analysis for the entire car market, we decided to focus our analysis on one particular segment, namely compact cars. This segment was selected for the analysis since it is one of the most important segments in the car market in terms of absolute sales. Furthermore, it seemed important to only include those models in the study that had a significant market share and that competed for the same customers. Following these criteria, 16 cars were selected as the stimulus material for the study (i.e., Alfa 147, Audi A3, Citroën C4, Fiat Grande Punto, Fiat Sedici, Honda Civic, Lancia Musa, Mini, Nissan Micra, Opel Corsa, Peugeot 207, Renault Clio, Smart ForFour, Suzuki Swift, Toyota Yaris and VW Cross Polo).



In order to obtain standardized pictures for the morphing procedure, all cars were rented in the same color (i.e., metallic grey) from several rental agencies and brought to a photographic studio. There, a professional photographer photographed the front and the side of all cars from an equal distance, mimicking the view a person would have when standing a few feet from the cars. The resulting pictures are depicted in alphabetical order in figure 2. Out of the pictures, we created two different morphs, one blending the features of the cars' frontal appearance and one blending the features of the cars' lateral appearance. The morphs and the pre-defined feature points are shown in figure 3.

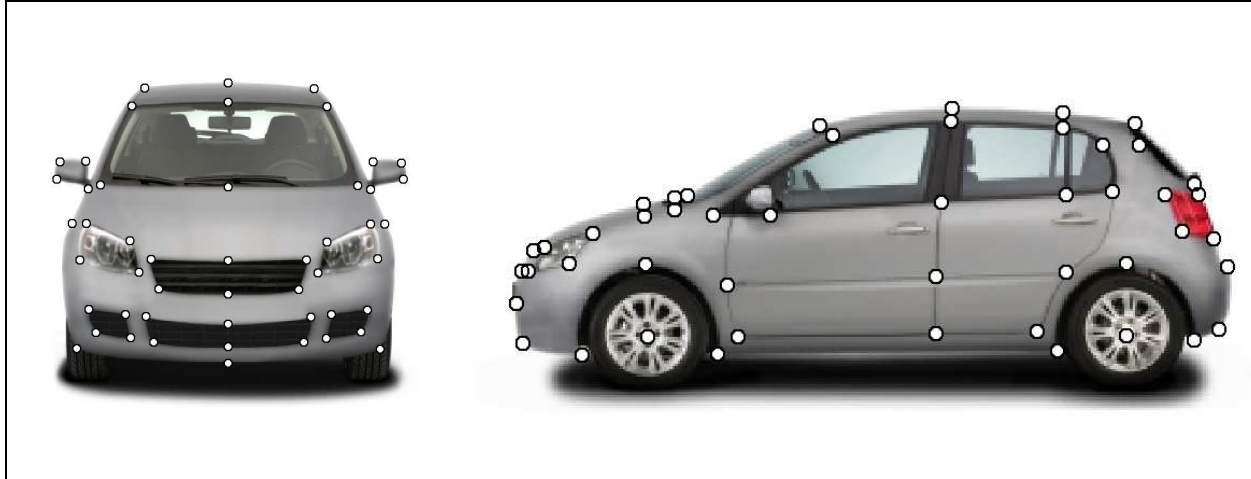


Figure 3. Definition of Feature Points

Study 1) Exploratory Analysis

Evaluation of Car Designs

1,547 potential buyers of new cars were asked to evaluate the 16 vehicles as part of a comprehensive online survey conducted in three different countries (Germany, United Kingdom, USA). Each participant received either the front or the side view so that the impressions would not mentally blend together. Of the 1,547 participants, 763 (Germany: 254; UK: 267; USA: 242) were asked to evaluate the front views and 784 (Germany: 284; UK: 264; USA: 236) were asked to rate the side views. On average, participants were 33 years old. In order to exclude any sequence effects, all stimuli were presented in a random order. Perception of the vehicles’ attractiveness was measured on 7-point bipolar scales (I don't like the car's design - I like the car's design).

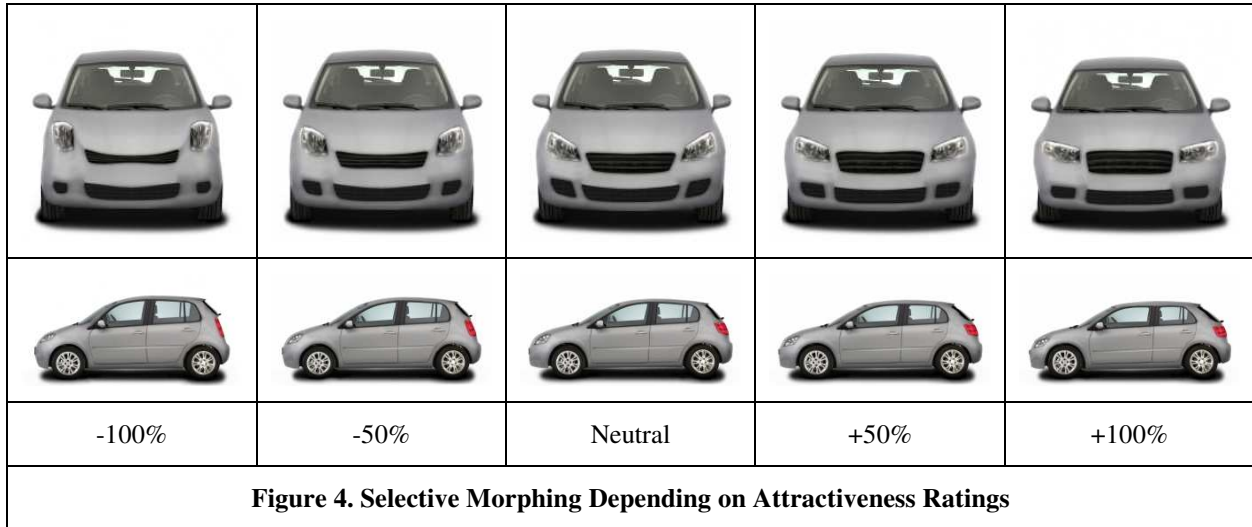
Table 1. Mean Evaluations of Cars with Respect to Attractiveness																
	Alfa	Audi	Citroen	Fiat Punto	Fiat Sedici	Honda	Lancia	Mini	Nissan	Opel	Peugeot	Renault	Smart	Suzuki	Toyota	VW
Front	4.12	4.43	3.45	3.40	3.49	4.65	3.17	4.59	2.87	4.01	3.62	3.31	3.13	3.23	3.00	4.23
Side	3.49	4.20	3.93	3.94	3.33	4.58	2.76	4.74	2.98	4.21	4.27	3.68	3.06	3.16	3.16	3.94

Before conducting any further analyses, we first tested whether there were any significant differences between participants from different countries. This analysis showed that the country variable on average only accounted for 1.5% of the variance in the attractiveness ratings of the cars. Hence, the country variable did not exert a significant effect on the dependent variables, such that the data were pooled across the three countries for all subsequent analyses. Table 1 shows the pooled mean evaluations of the 16 cars with respect to liking.

Extraction of Warping Dimensions

Next, we ranked the cars (both the front views and the side views) according to attractiveness ratings. A first morph was created from those vehicles evaluated as being particularly attractive (i.e., one standard deviation above the mean), while those cars that were not considered particularly attractive (i.e., one standard deviation below the mean) formed the basis for a second morph. For the front view the most attractive cars were Honda Civic, Mini, Audi A3 and VW Polo and the most unattractive cars were Toyota Yaris and Nissan Micra (cf. table 1). For the side views,

the most attractive cars were Mini and Honda Civic and the most unattractive cars were Smart ForFour, Nissan Micra and Lancia Musa (cf. table 1). Using the remaining cars with average evaluations, a third, average morph was created. Figure 4 shows the morphs of these three vehicle groups. In addition, Figure 4 also depicts two morphs of intermediate level of attractiveness. These morphs were created by moving the feature points of the norm vehicles 50% of the distance to the location of the feature points of the below-average and above-average vehicles (cf. figure 5). Based on these images, it is possible to identify those design features that are most influential in driving evaluations of attractiveness.



In figure 5, the arrows placed on the feature points of the average morph indicate the directions in which the feature points must be shifted in order to produce the proportions of the below-average morph (red/thin arrows) or the above-average morph (green/bold arrows). To depict morphed car images, feature points and warping dimensions within one picture, the rimage software package of the statistical software R was employed (Nikon Systems Inc. 2005). The length of a given arrow indicates how much the product shape would need to change at that feature point. Hence, longer arrows suggest that a particular point has a stronger impact on consumers' perception of attractiveness.



Several insights can be gained from these figures. In general, perceived attractiveness is sensitive to a relatively small number of feature points only. In particular, in the front view, variations in product shape near the headlights and radiator grill hold greater prominence than those near the windshield, side mirrors, and air intake vents. To achieve greater attractiveness, for example, the headlights need to have a less slanted orientation and the lower air intakes needs to be narrowed and lowered. In the side view, the important areas include the height of the vehicle, the steepness of the front windshield and the back window, the length of the engine hood, and the ratio of the length of front and back door.

Study 2) Confirmatory Analysis

The aim of the first study was to identify those design elements that are responsible for increasing a car's attractiveness. Due to the exploratory nature of the first study, the results are only correlative in nature and do not establish an unequivocal causality. In particular, we used existing car models whose ratings might be biased due to preexisting associations. Thus, to provide unequivocal evidence for the usefulness of our approach, we conducted a confirmatory study that employed experimentally manipulated images.

Procedure

A sample of 1,834 potential buyers of new cars were again recruited in three countries using an online panel. The participants randomly received either the front or side views. This resulted in 943 participants being shown the front views (Germany: 296; UK: 346; USA: 301) and 891 being shown the side views (Germany: 288; UK: 315; USA: 288). On average, participants were 32 years old. Participants were exposed to five images of fictitious cars in a random order. These included the images shown in figure 4; that is, the unattractive car (i.e., the -100% warp), the average car (i.e., the 0% warp), and the attractive car (i.e., the +100% warp). Furthermore, we created two intermediate levels of attractiveness through warping; that is, one image that falls between the unattractive and the average car (i.e., the -50% warp) and another image that falls between the average and the attractive car (i.e., the +50% warp). Participants were asked to rate each of the 5 vehicles with respect to its respective attractiveness using visual analog scales which recorded responses in increments of one in the range of zero to 1,000.

Results

The design of the study features a repeated measures structure for the dependent variable (i.e., perceived attractiveness) with the independent variable (i.e., five different levels of warping) manipulated within participants. Hence, the appropriate method for analyzing our data is a repeated measures analysis of variance (RM-ANOVA). Moreover, separate analyses were performed for the two views of the car (i.e., front view vs. side view). As in study 1, the country variable did not account for a significant amount of variance ($< 1\%$), such that the data were pooled across the three different countries. Table 2 provides the means and the standard errors for the five levels of the independent variable for both the front views and the side views.

	-100%	-50%	Neutral	+50%	+100%
Front	$M = 167.48$ ($SE = 6.44$)	$M = 401.12$ ($SE = 7.06$)	$M = 590.89$ ($SE = 6.37$)	$M = 613.55$ ($SE = 5.61$)	$M = 585.04$ ($SE = 6.00$)
Side	$M = 340.76$ ($SE = 7.94$)	$M = 468.25$ ($SE = 7.20$)	$M = 593.40$ ($SE = 6.30$)	$M = 616.96$ ($SE = 6.19$)	$M = 582.55$ ($SE = 6.69$)

The RM-ANOVA shows significant differences in the perceived attractiveness between the warping levels for both the front views ($F(4, 3768) = 1294.74$; $p < .001$; $\eta^2 = .579$) as well as the side views ($F(4, 3560) = 443.50$; $p < .001$; $\eta^2 = .333$). LSD post hoc contrasts show that for the front views each of the five factor levels differ significantly from each other ($p < .001$), except for the medium-morph and the 100%-warp ($p = .42$). For the side views the same pattern emerges: all levels differ significantly ($p < .001$), except for the contrast between the medium-morph and the

100%-warp ($p = .11$). Inspection of the means provided by table 2 reveals that both for the front views as well as for the side views a warping into the direction of the unattractive morph (-100%-warp) decreases the perceived attractiveness in a monotonic and accentuated fashion. Warping the average morph into the direction of the attractive morph (+100%-warp), however, only leads to an initial increase in perceived attractiveness, which reaches its maximum at the +50%-warp and levels down again at the +100%-warp. That is, modifying the shape of the car alongside the attractiveness vectors seems to translate into attractiveness ratings that follow an inverted u-shaped pattern. Put differently, the +50% warp seems to be sufficient to elicit maximal attractiveness ratings.

Study 3) Identifying the optimal warping extent

One limitation of the second study is that it relies on discrete manipulations of different warping levels. That is, it is not necessarily the case that the +50%-morph is indeed the optimal configuration for designing an appealing car. Alternatively, it is possible that the +50%-morph is only closer to the optimum modification than the +100%-warp, implying that the optimum is located somewhere between these two discrete levels (e.g., a +70%-warp). To gain more specific insights into optimum modification levels, we conducted a third study in which we relied on dynamic (participant-controlled) car images instead of static images representing discrete modification levels. That is, we developed an interactive graphics tool that allowed participants to adjust a continuously adapting car shape according to their attractiveness perceptions.

Procedure

The same participants as in the preceding study served as participants for this study. Those who had been assigned to the front (side) view condition were also confronted with front (side) views in this part of the study. Participants were provided with an interactive graphics tool which allowed them to modify the shape of the medium vehicle in the direction of the above-average product shape. At the start, the computer screen depicted the shape of the neutral vehicle (i.e., 0% modification). Participants were informed that a slider underneath the automobile image allowed them to reshape the automobile and were then asked to adjust the image such that, in their opinion, a maximal attractiveness was achieved. On the computer screen, the product shape was interactively modified in the direction of the above-average product shape (i.e., in the direction shown by the green/bold arrows depicted in Figure 5).

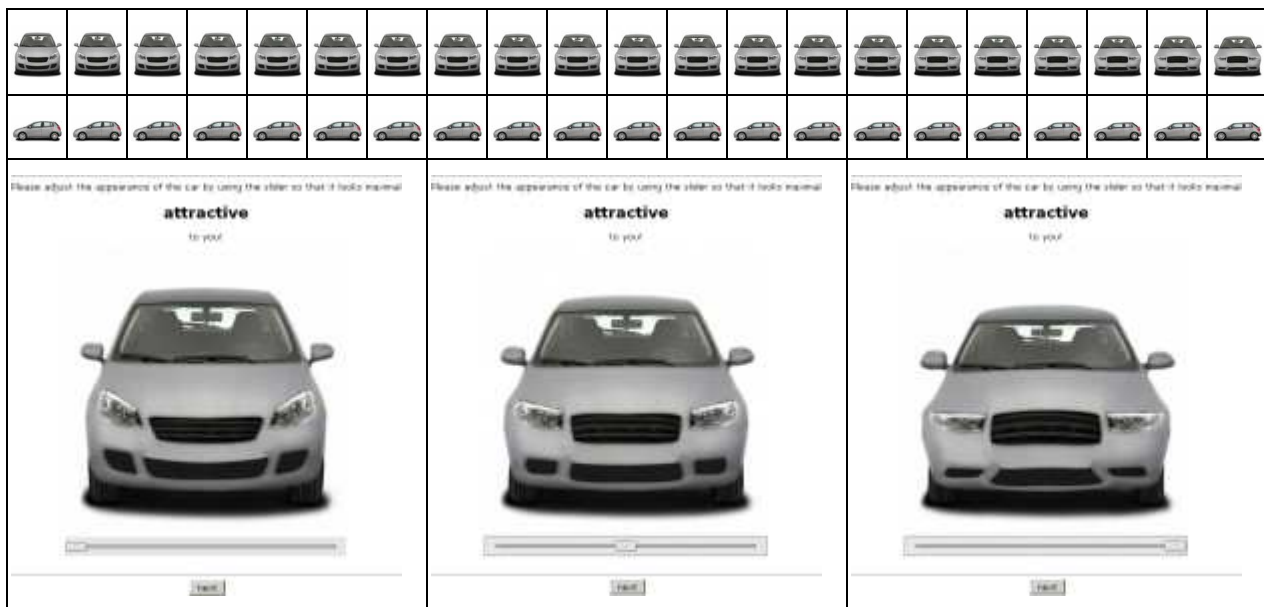


Figure 6. Optimizing Car Designs by Means of a Computer Assisted Method-of-Adjustment

Since this research focuses on examining how managers can enhance (rather than diminish) the perception of attractiveness, the study did not include below-average product shapes. The slider was designed with 20 equal increments in the range of 0% modification to 200% modification, with the initial position for all participants set to 0% modification (see figure 6 for screenshots of the initial image and two adjusted cars at +100% and +200% as well as all 21 frames for front views and side views). It is important to notice that although technically 21 discrete pictures build the basis for the adjustable car, subjectively the car changed continuously when participants moved the slider.

Results

Before determining the optimal levels of adjustment with respect to perceived attractiveness we again checked for any cross-country differences that might be relevant for the analysis. Again we found that country as a factor explains less than 1% in the variance of the slider adjustments which justifies an aggregated analysis across all three countries.

For the front views we found that on average participants moved the slider up to a 73.4%-warp level (SE = 1.78). To test whether this value significantly differs from the 50%-warp which was identified as a first approximation to the optimum in the second study, we performed a one-sample t-test with 50% as the critical test value. In accordance with the assumption that the true attractiveness maximum lies between the 50%- and the 100%-warp, we found that maximal attractiveness indeed differs significantly from the 50%-warp ($t(942) = 13.14$; $p < .001$). For the side views a 70.4%-warp level (SE = 1.99) was identified as the optimal level for maximal attractiveness which also differs significantly from the 50%-warp suggested as a first approximation by the preceding study ($t(890) = 10.27$; $p < .001$). These results are consistent with those results obtained using the static presentation of modified product shapes in the preceding study and allow for a more fine-grained estimation of the optimal extent of warping. That is, while systematically adjusting the shape of a product in relation to an average morph may enhance the aesthetic attractiveness of the product, one must also recognize that a point of over-modification exists, beyond which perceived attractiveness diminishes.

General Discussion

In sum, the results of three studies confirm that the method developed in this paper is a suitable means for optimizing product designs based on consumers' preferences. The design of a product is regarded as one of the core determinants of a buying decision for many product categories and therefore involves crucial managerial decisions. In the context of product design, two general types of questions await an answer. On the one hand, design-driven innovations are developed by the creative design departments and need to be evaluated with respect to potential market success by top management. On the other hand, from a user-centered design perspective, design departments are striving for a way to integrate consumer preferences into the design process at a very early stage to reduce expenditure of time and costs. That is, a tool is needed that allows to transform abstract consumer preferences into the most accessible format for the design department: direct visual information. Both of these goals may be reached by applying our approach and combining image morphing and warping techniques in the design process. That is, a design image generated through our approach may help designers in choosing between concurring design sketches and may also serve as a guideline or a source of inspiration for the designers' own creative work.

In this respect, the proposed approach may also serve as a kind of common language that may help to facilitate and focus the communication between different departments within a firm that are involved in the product design process. Hence, one may argue that the approach developed in this paper may reduce the tensions that are frequently encountered between design and other departments within a firm (Beverland 2005) and may contribute to a systematic exchange of information and thereby facilitate cross-disciplinary collaboration.

Furthermore, the interactive tool developed in the third study may also be used in the context of mass customization, which may especially be the case in industries in which different product designs can be manufactured at relatively low costs. As such, the marketing literature shows that consumers differ in their need for uniqueness and their preferences for unique, customized products (Tian et al. 2001). In other words, consumers may differ in the extent to which they prefer products that differ from the prototypical product design. In the current case, the prototypical design is encapsulated in the average morph and any deviation from this prototype can be considered as a way of customization. Thus, by means of this approach, consumers may be allowed to adjust a product according to their

desired level of prototype deviation. This approach may increase consumer utility and may result in higher purchase probability and willingness-to-pay.

From a theoretical perspective, the findings provide valuable insights into the psychological foundations of product aesthetics. In line with the findings on facial attractiveness (Perret et al. 1994), our studies show that consumers neither prefer perfect prototypicality nor an undirected deviation from the prototype; rather, they favor a very specific deviation from the prototype that is likely to convey some kind of higher order meaning. That is, systematic deviations in terms of shape and proportion may cause consumers to infer some very specific characteristics that have been previously stored in memory. Since the preference for systematic deviations shows only minor interindividual differences, it seems likely that people within a given cultural context may associate the same meanings with a particular deviation in shape and proportion. Although the present research did not uncover the specific rules underlying the relationships between shapes and product meanings, it nevertheless opens the door for future research endeavors in that direction. Furthermore, the result that findings in the field of human attractiveness can be replicated in a product design context is in itself a valuable insight and attests to the robustness and generalizability of previous research.

Although this research contributes both to the psychological literature on product aesthetics and the application of information systems, it also has some limitations that need to be noted. Specifically, our approach does not aim to replace the creative work of a designer. Since the approach is based on consumers' evaluations of existing designs, it is probably more suited for implementing incremental changes. However, it may be less suited for identifying radical changes and design milestones such as Apple's iMac. That is, numerous studies show that consumers are usually not very effective in suggesting radical improvements for product designs (Griffin and Hauser 1996; Veryzer 2005). In addition, image morphing and warping inevitably lead to the elimination of product-specific characteristics and emphasize those design elements that are common to all products in a given segment (although the elements may differ in their appearance). Thus, the creativity of designers is needed for generating deviations from global design recommendations and for imbuing a product with an individual, unique appearance and personality.

A further limitation of the presented approach is its restriction to product categories where all considered exemplars share a common first order shape. That is, it only works if all considered products share the same core features that can unequivocally be coded by feature points. In this respect, cars are an ideal context of application because due to legal restrictions and technological requirements all cars share the same elements such as headlights, windshield and grille and also the same global shape. For other product categories such as cell phones, where both the global shape and the configuration of elements have changed considerably over the last couple of years, it might be hard to implement the proposed approach and it might prove necessary to constrain the analysis to a subset of products that share sufficient characteristics.

In terms of future research, we only examined the viability of our approach in a single product category, namely cars. Hence, future studies may want to test our approach in categories that are somewhat less involving and less costly than cars. In a similar vein, due to financial restrictions we had to limit our investigation to a small set of exemplars (16) which certainly limited the potential of the approach to eliminate unsystematic variance between the cars. For a practical application of the approach, it would thus be desirable to extend the range of included product exemplars considerably to further increase the accuracy of the approach. Furthermore, all exemplars and all feature points were assigned the same weight in the morphing algorithm. It might, however, be possible that some car designs and/or some design features such as the headlights possess a disproportionate impact on the consumers' perceptual processes and should therefore receive more weight than other exemplars/features. Future research may examine this interesting possibility. Finally, we varied all design features simultaneously alongside the identified warping dimensions. While this approach allows for the identification of an ideal configuration, it does not illuminate potential interactions between design elements. To gain further insights into how specific design features may interact with each other to affect perceptions of attractiveness, future research may thus manipulate different design features in a complete experimental setting.

References

- Aggarwal, P., and McGill, A. L. 2007. "Is that Car Smiling at Me? Schema Congruity as a Basis for Evaluating Anthropomorphized Products," *Journal of Consumer Research* (34:4), pp. 468-479.
- Benson, P. J., and Perrett, D. I. 1993. "Extracting Prototypical Facial Images from Exemplars," *Perception* (22:3), pp. 257-262.
- Beverland, M. B. 2005. "Managing the Design Innovation - Brand Marketing Interface: Resolving the Tension between Artistic creation and Commercial Imperatives," *Journal of Product Innovation Management* (22:2), pp. 193-207.
- Bloch, P. H. 1995. "Seeking the Ideal Form: Product Design and Consumer Response," *Journal of Marketing* (59:4), pp. 16-29.
- Bornstein, R. F., and D'Agostino, P. R. 1994. "The Attribution and Discounting of Perceptual Fluency: Preliminary Tests of a Perceptual Fluency/Attributional Model of the Mere Exposure Effect," *Social Cognition* (12:2), pp. 103-128.
- Corneille, O., Huart, J., Becquart, E., and Brédart, S. 2004. "When Memory Shifts Toward More Typical Category Exemplars: Accentuation Effects in the Recollection of Ethnically Ambiguous Faces," *Journal of Personality and Social Psychology* (86:2), pp. 236-250.
- Demirtas, E. A., Anagun, A. S., and Koksall, G. 2009. "Determination of Optimal Product Styles by Ordinary Logistic Regression versus Conjoint Analysis for Kitchen Faucets," *International Journal of Industrial Ergonomics* (39:5), pp. 866-875.
- Dion, K., Berscheid, E., and Walster, E. 1972. "What is Beautiful is Good," *Journal of Personality and Social Psychology* (24:3), pp. 285-290.
- Fechner, G. T. 1876. *Vorschule der Ästhetik*, Leipzig, Germany: Breitkopf & Härtel.
- Griffin, A., and Hauser, J. R. 1996. "Integrating R&D and Marketing: A Review and Analysis of the Literature," *Journal of Product Innovation Management* (13:3), pp. 191-215.
- Herba, C., Heining, M., Young, A., Browning, M., Benson, P., Phillips, M., and Gray, J. 2007. "Conscious and Nonconscious Discrimination of Facial Expressions," *Visual Cognition* (15:1), pp. 36-47.
- Huertas-Garcia, R., and Consolación-Segura, C. 2009. "Using Statistical Design Experiment Methodologies to Identify Customers' Needs," *International Journal of Market Research* (51:1), pp. 115-136.
- Ji, H. I., Kamachi, M., and Akamatsu, S. 2004. "Analyses of Facial Attractiveness on Feminised and Juvenilised Faces," *Perception* (33:2), pp. 135-145.
- Just, L., and Salvador, R. 2003. "Marketing Meets Design: Conference Summary," *Marketing Science Institute* (1:03-001), pp. 37-47.
- Kreuzbauer, R., and Malter, A. J. 2005. "Embodied Cognition and New Product Design: Changing Product Form to Influence Brand Categorization," *Journal of Product Innovation Management* (22:2), pp. 165-176.
- Landwehr, J. R., Labroo, A. A., and Herrmann, A. 2009. "The Pervasive Effect of Aesthetics on Choice: Evidence from a Field Study," *Advances in Consumer Research* (36), pp. 751-752.
- Langlois, J. H., and Roggman, L. A. 1990. "Attractive Faces are only Average," *Psychological Science* (1:2), pp. 115-121.
- Mandler, G. 1982. "The Structure of Value: Accounting for Taste," in *Affect and Cognition: The 17th Annual Carnegie Symposium*, M. S. Clarke and S. T. Fiske (eds.), Hillsdale, NJ: Lawrence Erlbaum Associates, pp. 3-36.
- Michalek, J. J., Feinberg, F. M., and Papalambros, P. Y. 2005. "Linking Marketing and Engineering Product Design Decisions via Analytical Target Cascading," *Journal of Product Innovation Management* (22:1), pp. 42-62.
- Miesler, L., Landwehr, J. R., Herrmann, A., and McGill, A. L. 2010. "Consumer and Product Face-to-Face: Antecedents and Consequences of Spontaneous Face-Schema Activation," *Advances in Consumer Research* (37), pp. 536-537.
- Meyers-Levy, J., and Tybout, A. M. 1989. "Schema Congruity as a Basis for Product Evaluation," *Journal of Consumer Research* (16:1), pp. 39-54.
- Nikon Systems Inc. 2005. "rimage: Image Processing Module for R," *R package version 0.5-7*.
- Perrett, D. I., May, K. A., and Yoshikawa, S. 1994. "Facial Shape and Judgements of Female Attractiveness," *Nature* (368:6468), pp. 239-242.
- Reber, R., Schwarz, N., and Winkielman, P. 2004. "Processing Fluency and Aesthetic Pleasure: Is Beauty in the Perceiver's Processing Experience?," *Personality and Social Psychology Review* (8:4), pp. 364-382.

- Reber, R., Winkielman, P., and Schwarz, N. 1998. "Effects of Perceptual Fluency on Affective Judgments," *Psychological Science* (9:1), pp. 45-48.
- Silayoi, P., and Speece, M. 2007. "The Importance of Packaging Attributes: A Conjoint Analysis Approach," *European Journal of Marketing* (41:11/12), pp. 1495-1517.
- Steyvers, M. 1999. "Morphing Techniques for Manipulating Face Images," *Behavior Research Methods, Instruments, & Computers* (31:2), pp. 359-369.
- Tian, K. T., Bearden, W. O., and Hunter, G. L. 2001. "Consumers' Need for Uniqueness: Scale Development and Validation," *Journal of Consumer Research* (28:1), pp. 50-66.
- Veryzer, R. W. 2005. "The Roles of Marketing and Industrial Design in Discontinuous New Product Development," *Journal of Product Innovation Management* (22:1), pp. 22-41.
- Winkielman, P., Halberstadt, J., Fazendeiro, T., and Catty, S. 2006. "Prototypes are Attractive because they are Easy on the Mind," *Psychological Science* (17:9), pp. 799-806.
- Wolberg, G. 1994. *Digital Image Warping*, Los Alamitos, CA: IEEE Computer Society Press.