EMOTIONAL BIONICS - A PICKUP TRUCK IS A LION! A STUDY USING EMOTIONAL PROFILING TO ANALYSE BIONIC ANALOGIES IN CAR DESIGN

Susan Gretchen ZÖLLERA [a], Tina SCHRÖPPELB [b], and Sandro WARTZACKC [c]

[a] *Friedrich-Alexander-University Erlangen-Nuremberg, Germany,* zoeller@mfk.fau.de
[b] *Friedrich-Alexander-University Erlangen-Nuremberg, Germany,* schroeppel@mfk.fau.de
[c] *Friedrich-Alexander-University Erlangen-Nuremberg, Germany,* wartzack@mfk.fau.de

ABSTRACT

So far, bionic design has mainly been systematically applied to support functional solutions. But in recent times, subjective aspects in product quality became increasingly important to users too. Under the aspect of a sustainable, targeted value creation for users, bionic design may also help to better address users' subjective needs in product design. Therefore, a new method is presented. Its first step is the numeric and perception-related investigation of main geometrical criteria in object shape changes between technical solutions and their bionic models. The second step is the identification and utilization of impressions analogies between the two domains. Thus, subjective similarities between the product and its bionic model are examined both in geometrical and in impressions respect in order to derive implications for the field of Emotional Bionics.

Keywords: *Emotional Bionics, Subjective Value Creation, Kansei Engineering, Design Analytics.*

1 Introduction: The Potential of Bionics in Emotional Design

The basic principle of bionic design, and the analogy adoption of a biological model to technical products influenced many designers so far. The ability of nature for integrative form and function design is unsurpassed. Hence, bionic inspired technology has proven to be more sustainable, efficient, and robust to raise the functionality of technical products. Moreover, besides their functional advantages, many application examples further demonstrate that design inspired by nature often shows to be very attractive to users [1].

In recent times, subjective aspects in product quality became increasingly important to users too. Indeed, systematic bionic design has mainly been applied to support functional solutions so far, but under the aspect of a sustainable, targeted value creation for users, bionic design may also help to better understand and to address the users' subjective needs in product design. In this contribution, a systematic approach to understand bionic mechanisms in subjective value perception of technical products is presented. Therefore, the bionic design analogies are investigated under objective Gestalt variation and subjective user impression aspects. In this way systematic bionic design could also be used to unlock the Nature's subjective design potential for a sustainable user satisfaction.

2 State of the Art

2.1 Bionic Design and Emotions

Biologically inspired design or bionic design as a discipline investigates structures, processes and design principles of biological systems and transfers them into technical problem solving [1]. Therefore, basic procedures and design principles do exist that are firmly integrated into the bionic product development process [2] [3]. E.g., different computational approaches help to link biological and engineering systems and allow a solution adaptation from different domains. In doing so, they formalize and functionalize design principles in order to support a systematic bionic design [4].

Measuring semantics and emotional responses to bio-inspired design has been done, e.g. to investigate animal posture [5]. Therein, formal connections between bio-inspired sources and design solutions have been examined. Research shows that there is a correlation of emotional terms and semantic descriptions between bionic and technical models. Also design formalization and computational creativity is applied in bionics research. Therefore, cognitive psychology theories [6] or genetic algorithms [7] are used to generate new design solutions. Especially in the case of bionic design for subjective value creation, the bionic principle has been decomposed to formal models of (visual) perception considered in the context and of aesthetics and Gestalt principles [6]. However, a transfer into systematic design synthesis for user impressions and therefore addressing the subjective value of a product is outstanding.

2.2 Product appearance and Gestalt analysis

A product's overall appearance is mainly defined by its Gestalt (ger. Form, shape), represented by perceptually relevant pattern elements for human vision like lines, edges, and more gradual changes in contrast [8] [9]. A computational approach that investigates a product's Gestalt is presented by ORSBORN ET AL, which used principal components analysis to extract the main visual characteristics of technical products [10]. In doing so, design patterns and user recognition can be investigated. Those computer-aided procedures help to formally analyse user feedback to subjective product experience depending on different design characteristics (e. g. [11]).

2.3 Kansei Engineering and ACADE

Kansei Engineering as a form of emotional engineering supports the formal interpretation of users' subjective experience. It links design changes to their impact on user's subjective impression of the product [12]. An approach that takes these relations between product design changes and user impressions, and systematically links them to the individual's subjective evaluation system is ACADE [13]. It works with specific quantitative impressions profiles (semantic differentials with ratings between opposite word pairs) that represent the full spectrum of user attitudes towards a product. They are used to subjectively characterize both the product and the user. In doing so, an overall impressions profile of both is derived. In this way, an optimal product-user-fit can be targeted [14].

Subsuming, the Gestalt of a product plays a major role in subjective human perception and therefore for subjective value creation. In order to derive a systematic and transparent procedure to use bionic principles for subjective value creation, ACADE as quantitative emotional engineering tool can be used. It links quantitative Gestalt variation with subjective qualities. Subjective bionic principles may thus become quantitatively assessable for product design.

3 Methodology and Application Example

3.1 Methodology and core questions

The aim of the method is to unveil bionic mechanisms for subjective value creation of technical products. Therefore, existing analogies are examined in order to create a systematic approach to describe these mechanisms. It helps to better understand relations of bionic principles in subjective value perception of technical products. Therefore, the design analysis is split into three main steps, wherein both quantitative and qualitative methods are used in order to compare analytical (objective) and intuitive (subjective) design aspects (see Fig. 1).

For the analytical investigation, a Gestalt analysis using principal components analysis (PCA) is processed. Therein, the products' form variation is examined numerically. Those areas that show highest Gestalt variation are Areas of Variance (AoV) (analysis A).

For the human perception analysis, image-based recognition recording is used. By asking users via survey to indicate those areas that they are mostly focusing on, the product design's Areas of Attention (AoA) are derived (analysis B).

Lastly, an impressions analysis is conducted in order to derive insights into unique subjective qualities of technical solutions and their bionic models. Therefore, ACADE is applied to get characteristic impressions profiles that can be compared to each other (analysis C).

Building on that, similarities between the product and its bionic model are examined in two ways. First, Gestalt variation and the users' intuitive design recognition are analysed to unveil the products' Areas of Interest (AoI) (A + B). Thus, it is highlights differences between objective design variations and subjective user attention, differentiating subjectively relevant areas from objective changes. With respect to design differences between natural models and technical solutions, the ACADE analysis unveils subjective analogies by comparing the complementary profiles and Gestalt specifics (A+B+C). The combination of the three different analysis lastly allows the derivation of design implications that allow systematic Emotional bionic design.

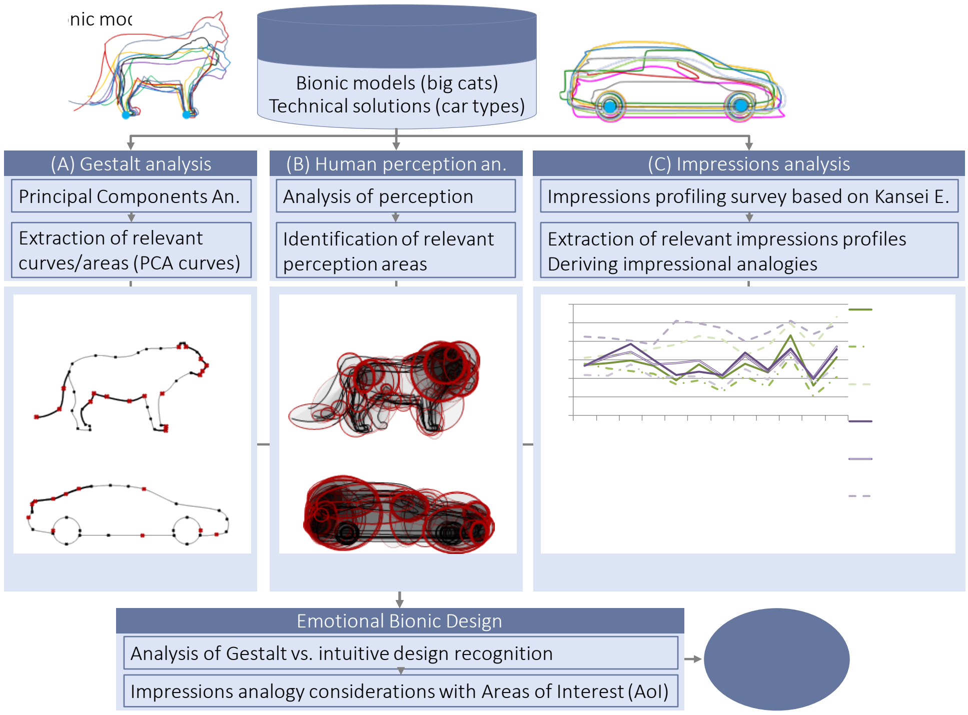

Fig. 1. Structural Approach of an Emotional Bionics Analysis.

3.2 Application example

As indicated in Fig. 1; a sample of cats and a sample of cars are chosen for the application study. On one hand, cats have already been bionic models for many successful car designs - only to mention the Ford Mustang or the Jaguar as a brand name here. Therefore, valuable study outcomes are expected with regard to bionic analogies. On the other hand, very different subjective impressions are expected as big cats as well as cars are often experienced very emotionally differentiated, e.g. ranging from very cute (like a kitten or a VW Beetle) to very dangerous (like a lion or a Dodge RAM). Each of these natural models and technical solutions pose a very distinct overall impression. In this sense, variations of both subjects cause very different user impressions that raise the quality of the study outcome.

Within each sample, different characteristic silhouettes of cats and car types were collected. Subsuming there are 6 different cats (a jaguar, a tiger, a leopard, a snow leopard, a cheetah, and a lion) and 8 different cars (a family van, a 3-doors and a 5-doors limousine, a station wagon, a SUV, a pickup truck, a convertible, and a sports car). To check the targeting of the study, a domestic cat and a stretch limousine are additionally admitted. A domestic cat, as an example, should provoke very different impressions to users (like cuddly, clumsy, playful …) and a stretch limousine is only used for special purposes instead of daily uses. Furthermore, it will be investigated whether the areas of attention widely differ there. Lastly these 2D representations are standardized via feet distance (cats) and wheel distance (cars).

4 Study results

The study is conducted using the standardized silhouettes of cats and cars and a two-part survey to subjectively characterize these technical solutions and their bionic models. 20 users were firstly asked to encircle those areas within each cat's and car's design where they put most attention to (for analysis B). Secondly, they were asked to fill in impressions profiles for each silhouette that base on characteristic semantic differentials like “high-value/simple” or “exclusive/usual” (for analysis C). Therefore, the ACADE structure was used that comprises a predefined set of opposite word pairs (semantic differentials) to measure users' subjective product value [14].

In the following, the results of the outlined three analyses are presented. First of all, the Gestalt analysis is conducted using PCA (analysis A). It shows that there are differences in the data interpretation, depending on the dimensional reference system (x-axis, y-axis, and combined). Nevertheless, some dominating curves appeared in all three dimensions that indicate the designs’ objective Gestalt variation. On the contrary, within the human perception analysis (analysis B), some defined design areas show to be characteristic for users to get their overall impression. Within the impression analysis (analysis C), the survey feedback unveils that there are distinct impressions profiles for each cat and car model. Due to high response consistencies, these profiles seem to be commonly characteristic and give hints to some general bionic clichés in society.

Lastly, an integrated analysis including all three analyses is conducted. Their findings will be reflected and subsumed to general statements regarding Gestalt approaches in the bionic design context of subjective value creation.

4.1 Gestalt analysis

For an analytical analysis of the objects, a PCA is conducted as computational form of Gestalt analysis by strictly following ORSBORN ET AL. [10]. Therein, the geometrically described silhouettes of object variations are analysed in order to identify the main components of the object's structure.

First of all, an atomization of the 6 cats’ and 8 cars’ silhouettes is processed to represent the objects by vectors, scalars, and angles [10]. Therein, characteristic design points are extracted to fully describe the outlines of each object sample. It is ensured that each object contains all design points within the two input data sets. For the following principal components decomposition, the data is further prepared by norming (mean value subtraction) and standardization. Thereafter, the load matrix with principal components is created, whereas the components are reduced to the only important ones using the KAISER'S Criterion (EIGENVALUE >1). In doing so, dominant points and relevant curves can be identified [10].

The PCA is processed separately for 7 cats with 2 dimensions and 40 sample points and 8 cars with 2 dimensions and 31 sample points. In a sum, six different resulting data sets are created, depending on the analysis direction (x-axis, y-axis, integrated x+y-axis). Therefore, the vectors of the PCA data sets are split into their x- and y-parts. Fig. 2 (left and middle) exemplarily shows the results of the so derived separate PCAs for a tiger. Whereas all analyses show high relevance of e. g. the head section of a cat in general, the details can strongly differ, e. g. regarding the cat's lower jaw or the neck silhouette. For an integrated analysis, the x- and y-parts are subsumed, showing highest numeric deviations in the tail, the chest and the head of the animal (right). These areas with highest numeric deviations are defined as Areas of Variance (AoV).

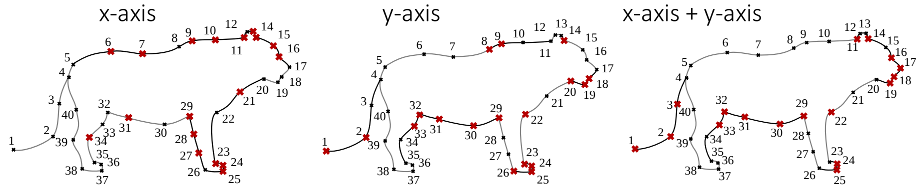

Fig. 2. Dimensional differences in PCA output: main curves (red) depending on x-axis vector parts (left), y-axis vector parts (middle) or the addition of x- and y-axis vector parts (right).

4.2 Human perception analysis

The participants of the survey were asked to circle those areas they were paying most attention whilst characterizing the objects by the given impressions (Fig. 2, left). Therefore, the size and number of these areas are not limited. In this way, object specific information about the users' design perception is quantitatively gathered. The feedbacks from every participant for the technical models and their bionic models are then cumulated. By superimposing their feedbacks through transparent circular fields, the Areas of Attention (AoA) represent the users' most recognized design areas of each model (Fig. 3, right).

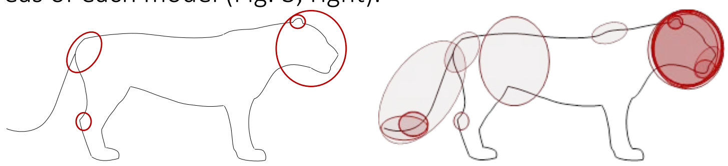

Fig. 3. Example of single feedback (left) and Areas of Attention (AoA) of a jaguar (right)

In a sum, these AoA show high homogeneity regarding the main attention areas for each model throughout the survey feedbacks. Each of it has not more than two main focus areas (in the example it's the head and the tail of the jaguar). Concluding, all provoked impressions may be derived by more or less the same perception areas, widely independent from the single person.

4.3 Impressions analysis

In the third analysis, the individual impressions profiles of each cat and car type are gathered following the ACADE procedure [14]. In this sense, the impressions profiles consist of 12 semantic differentials that are rated from 1 to 10 (Fig. 4, axes). The results' variety of each impression for one single object is low, showing that both the biological models and the technical models have clear, distinct impressions profiles to the number of persons. The mean values of all users for each impression are thus aggregated to build the overall impressions profile for every cat and car. In this sense, each of the objects is assigned to a unique impressions profile described by mean value and standard deviation of the return data on users' impressions. All impressions profiles are depicted in Fig. 4 (lines), compared per sample. It shows that there is a variation both in composition (structure) as well as in extent (parallelism). Comparing the cats to the cars' impressions profiles, there is equal variance in single impressions values. Mean standard deviations of 2.33 for cats and 2.56 for cars show high variety amongst different object variations. In more detail, the respective profiles show characteristic expressions and the additional check-examples (domestic cat and stretch limousine) succeeded. As an example, a lion was experienced to be highly masculine and strong whereas a cheetah was more female and fragile.

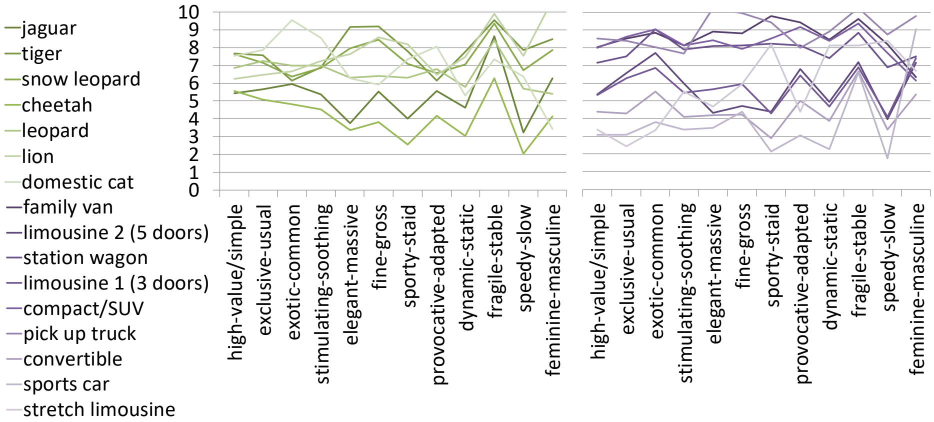

Fig. 4. Selected impressions profiles of cats' (left) and cars' variations (right) conducted with ACADE [14]

4.4 Emotional Bionic Design

The application study with the three-analysis unveiled two main findings that contribute to a systematic emotional bionic design: The first insight affects the source of subjective quality. A comparison of objective Gestalt analysis (analysis A) and human perception analysis (analysis B) shows high differences between actual design changes and user attention (AoV and AoA). The second insight affects the analogy of impressions. Comparing both the bionic models' and technical solutions' impressions profiles (cats and cars), the impression analysis (analysis C) shows higher similarities between specific cats and cars than amongst cats' and cars' sets themselves. These insights allow the derivation of new design implications in the context of emotional bionics.

Source of subjective quality: Gestalt analysis versus human perception. Fig. 5 illustrates the overall AoA for bionic models (cats) and technical solutions (cars) on the left-hand side, derived from human perception analysis. Therefore, all AoA from cats and cars are superimposed, wherein the AoA of the cats were more consistent than AoA of cars. Apart from that, both cats and cars show characteristic AoA at the upper head (front) and the tail (back) of the cat (car). On the right-hand side of Fig. 5, the results from the PCA as Gestalt analysis method are presented. Whereas the head and the tail of the cats remain as highly relevant, the cars' deviations in the front are not relevant from an objective point of view. The back of the cars, indeed, is also considered as relevant. Concluding, objective Gestalt analysis states only few similarities between cats' and a cars' design variation.

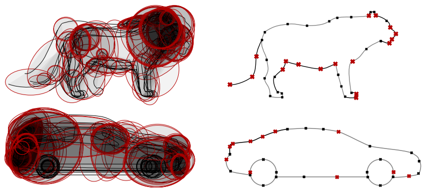

Fig. 5. Comparison of superimposed Areas of Attention (AoA) and Areas of Variance (AoV)

Differences in the results of the objective, numeric Gestalt analysis and the human perception analysis effectively show that human attention does not only recognize deviations between a model's shape and the commonality to other representatives of a group, but also general particularities that may not be considered as being relevant by numeric Gestalt analyses: Comparing objective Gestalt variation to the users' most attended design areas (analyses A and B), those areas that are perceived most relevant for impressions creation do not necessarily depend on actual numeric design variation; they are Areas of Interest for subjective design (AoI).

Analogy of impressions: The subjective similarity between bionic pairings. Due to its similar data structure, cats and cars can be compared immediately regarding their characteristic impressions profiles (analysis C). This comparison of both technical solutions (cars) and their bionic models (cats) show the potential of emotional bionics: Whereas each domain shows high variation amongst car or cat types, high similarities between specific cars and cats can be stated.

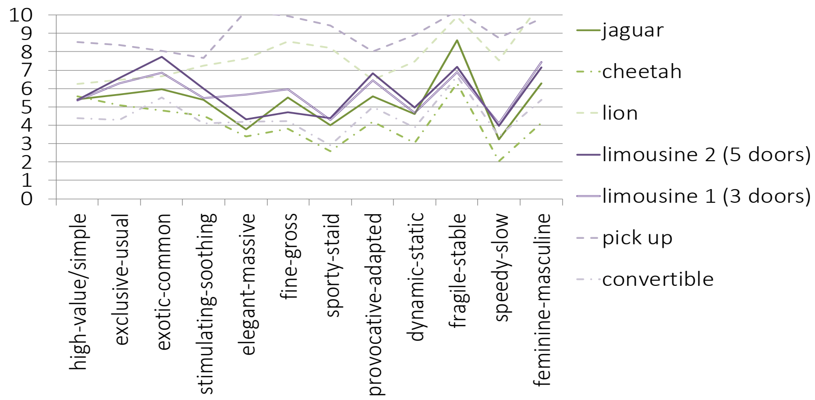

Fig. 6. Similarity analyses of impressions profiles, selected bionic models & technical solutions

As highlighted in Fig. 6, e.g. a pick-up truck (car) actually has high impressions similarities with a lion (cat). In the same row, a limousine (car) is subjectively similar to a jaguar. Contrarily, a jaguar and a lion are perceived very differently and so are a pick-up truck and a limousine: These similarities indicate the bionic potential for the respective pairings.

Design implications. Insights show that there are specific geometrical and impressions analogies between technical products and their respective bionic models, after which a product is valued by users. Whereas objective Gestalt analysis is not able to unveil design analogies from a quantitative point of view, human perception analysis shows relevant areas that are similar for both the bionic models and the technical solutions. Furthermore, a high similarity of impressions profiles in both models is stated. It shows that subjective bionic and technical counterparts can be assigned analytically.

In the bionic design context, studies following up this analytical approach represent an objective way how to align the subjective overall impressions of technical products to their bionic model. First of all, a characteristic overall impression of a bionic model is concretized using impression profiles. In this sense, technical solutions and bionic counterparts can be immediately detected due to their profile similarity; as well as their remaining differences. Furthermore, the study shows that users do not necessarily pay most attention to design areas with highest objective variance (AoV). Indeed, there are distinct areas that are most focused by all users (AoA). In these areas (Areas of Interest), the Gestalt of a technical solution can now be systematically aligned with respect to the impressions profile of the bionic model. Therefore, the application of ACADE in bionic design strategy for subjective value creation is suggested as it allows to target these similarities [14]. In doing so, characteristic design features determining the appearance of a focused bionic model could be stringently abstracted and integrated into new product design creations. The associative process in bionic design for technical products is thus objectified to a certain stage. This offers a way to communicate bionic principles to all parts of the product design process by providing objective parameters. Consequently, subjective bionic associations are systematically deducible. With the information about functional analogies derived by this procedure, designers can now better understand where subjective value is created, what the geometrical drivers of impressions changes are and how analogies to bionic models may be used.

5 Conclusions and Outlook: The Future of Bionic Design in Subjective Value Creation

Bionic design affects all areas of product development. As nature is the ultimate origin of all existence and our needs, it is not very surprising that nature is also responsible for our emotional ability and feelings. May it happen consciously or not, everybody tends to evaluate technical products to bionic models as these forms the archetypes of our environmental system our evaluation consists of. So far, this "natural potential of attractiveness" was used rather intuitively in the product creation process. Indeed, it is only reasonable to investigate whether an analytical approach to capture relations between bionic models and technical products in the design for subjective value does exist. Subjective value creation has not been payed much attention to so far but is of rising importance. Thus, bionic design may be successfully fostered in this context. The outlined systematic approach helps to understand analogical processes in bionic design from a subjective point of view and provides systematically derived, reasonable insights.

Nevertheless, the complexity of the human feelings, being part of the inconceivable system of Mother Nature, will never be understood completely. So, all efforts made in this direction may rest fuzzy, gathering only fragments of our perception by which we try to understand our being every day.

References

Nachtigall, W. (2006). *Biologisches Design: Systematischer Katalog für bionisches Gestalten*. Springer, Berlin.

Helms, M., Swaroop S., Vattam, A.K., & Goel, S. (2009) Biologically inspired design: process and products. *Design studies, 30.5*, 606-622.

Coelho, D. A., Versos, & C. AM. (2010). An approach to validation of technological industrial design concepts with a bionic character. In: *Proceedings of the International Conference on Design and Product Development (ICDPD'10)*.

Nagel, J.K., & Stone, R.B. (2011). A systematic approach to biologically-inspired engineering design. *ASME 2011*, *American Society of Mechanical Engineers*, pp153-164.

Kim, J., Bouchard, C., Bianchi-Berthouze, N., & Aoussat, A. (2011). Measuring semantic and emotional responses to bio-inspired design. *Design Creativity 2010, Springer*, pp131-138.

Minfeng, H., & Liming, F. (2011). On auto bionic modelling design study based on cognitive psychology theories. *International Conference on Mechatronic Science, Electric Engineering and Computer (MEC), IEEE*, pp. 1641-1644.

Cluzel, F., Yannou, B., & Dihlmann, M. (2010). *Evolutive design of car silhouettes using an interactive genetic algorithm.*

Altes, R.A. (1976). Bionic image analysis using lines and edges. Math. *Biosciences 31*(3-4), 317-339 .

Lugo, J.E., Schmiedeler, J.P., Batill, S.M., & Carlson, L. (2015). Quantification of classical gestalt principles in two-dimensional product representations. J. *of Mech. Design, 137*.9.

Orsborn, S., Boatwright, B., & Cagan, J. (2008). Identifying product shape relationships using principal component analysis*. Research in Eng. Design, 18*.4, pp. 163-180.

Hsiao, S.W., & Yuan, L.C. (2000). Form and texture effects on product image. In: *Proceedings of the Human Factors and Ergonomics Society, Annual Meeting*.

Nagamachi, M. (2010). *Kansei/affective engineering*. CRC Press, New York.

Kett, S.G., Schmitt, B., & Wartzack, S. (2017). What the statistics tell us-How to use empiric data in design for emotional impressions. In: *International Conference on Research into Design*, Singapore: Springer.

Zöller, S.G., & Wartzack, S. (2017). Considering users' emotions in product development processes and the need to design for attitudes. *Emotional Engineering, 5*, 69–97.