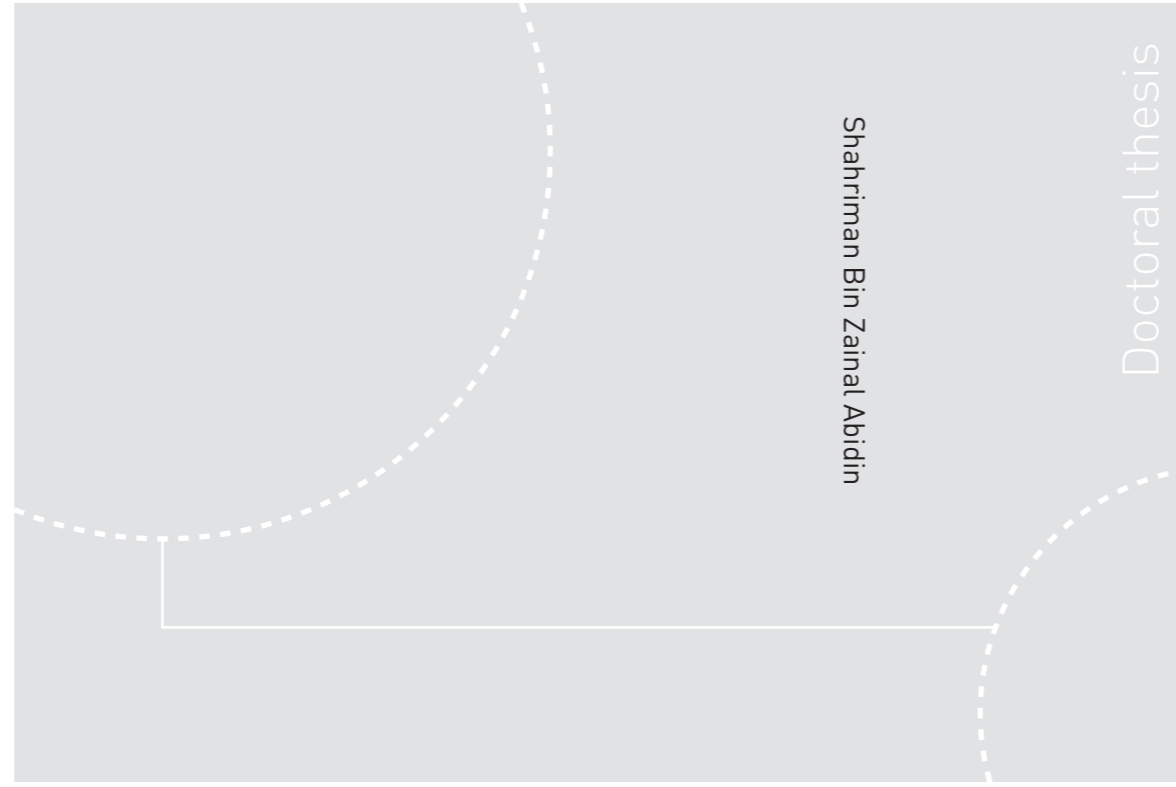


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Shahriman Bin Zainal Abidin  
Practice-based design thinking  
for form development and  
detailing

**NTNU**  
Norwegian University of  
Science and Technology  
Thesis for the degree of  
Philosophiae Doctor  
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Trondheim, October 2012

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## Abstract

Automotive design is a specialized discipline in which designers are challenged to create emotionally appealing designs. From a practice perspective, this requires that designers apply their hermeneutic as well as reflective design thinking skills. However, due to the increasing demand for new car models, it is not always possible to keep generating new car designs without some form of assistive means. Therefore, it is common practice to use Automated Morphing Systems (AMS) to facilitate and accelerate the design process in the automotive industry. However, AMS, which is an efficient algorithmic driven tool for form generation, lacks the emotional knowledge of human beings, as well as the ability to introduce a “creative” and preferably a “winning” design.

The purpose of this research is to study designers' reasoning about product (automotive) form, their form generation activity, and the implications of these. The research objective is to understand how designers generate forms driven by their implicit values, beliefs and attitudes towards designing, and how these are supported by their visualization and representation skills. Four research questions have been formulated in order to get a firm answer posed in this research.

Generation of measurable and testable data – which involved both qualitative and quantitative research to gather and analyze implicit and explicit designer's knowledge – constituted the main empirical effort for this thesis. A design research methodology framework consisting of three different parts was used in this data gathering exercise. These parts are: descriptive study I, prescriptive study, and descriptive study II. They involved methods such as surveys, observation studies and evaluation studies. Master's students' evaluations as well as the designers' own interpretations of their sketches – which represent the sequence of morphed forms – were considered essential aspects of the empirical studies.

The findings of this study can be summarized as follows:

1. Approaches in form development among designers vary due to their experiences, which affect their sketching abilities, activities, and implicit thinking patterns. In their sketching and form development activities, designers emphasize the most informative views, such as façade and three quarter front views, compared to other views of the car. Rather than adopt a uniform transformation strategy which includes the entire car, they also select what elements to morph.
2. In manual form generation, designers contribute with their personal and creative input in the development of the forms of the overall car, its selected items, and regions that determine the overall character of the car. Major differences in the morphing approaches applied by designers and automated CAD systems reside in the recognition and interpretation of the meaning of form elements.
3. Considering the inability of AMS to morph selectively and inconsistently, as well as to introduce ambiguity and variance, it is suggested here that AMS may be useful only for convergent transformation, which typically occurs during the later stages of the styling process.

4. Although perceptions vary according to how representations are presented in the morphing process, the Perceptual Product Experience (PPE) framework can still be considered a useful tool for establishing familiarity, for understanding quality characteristics and the nature of the product, and, finally, for determining meanings and assessing the values of form elements.

In conclusion, the work presents a descriptive model for practice-based design thinking about form development in automotive design. Manual interpolative morphing has been the focal area of study. The study categorizes meaning with respect to designer perception. Based on the study of manual morphing exercises, a new methodology of analyzing form syntactics, pragmatics and semantics related to design thinking, form development, and automotive design has been developed.

## Acknowledgements

Research at Philosophiae Doctor (PhD) level is not a simple task. Especially when we want to study design thinking related to form development in automotive design. However, working on a PhD at the Norwegian University of Science and Technology (NTNU) in Trondheim, Norway, was a great experience for me. This is not least because NTNU allows inter-disciplinary and cross-disciplinary studies.

I started my PhD studies at NTNU in January 2006. The person who brought me here was Professor Dr. Ken Friedman. I still remember what he said: “...*PhD is a research degree and a license for those who practice and teach research.*”

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Trondheim, April 2012  
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# Table of Contents

<i>Abstract</i>	<i>iii</i>
<i>Acknowledgements</i>	<i>v</i>
<i>Table of contents</i>	<i>vii</i>
<b>1. Introduction</b>	<b>1</b>
1.1 Automotive design	1
1.2 Form development in automotive design	2
1.3 Visualization and representation to facilitate form development	4
1.4 Aims and objectives	5
1.5 Research questions	6
1.6 Limitations	6
1.7 Thesis structure	7
<b>2. Frame of reference</b>	<b>8</b>
2.1 Syntactic, pragmatic and semantic issues related to form development	8
2.2 Model of experience	13
2.3 Computer aided design and modeling systems	15
2.4 The concept of morphing and use of its techniques	17
2.5 Automated morphing systems (AMS) in automotive design	19
<b>3. Methodology</b>	<b>22</b>
3.1 Design research methodology	22
3.2 Research approach	23
<b>4. Results</b>	<b>26</b>
4.1 Terminology of qualitative structure in automotive design	26
4.2 Linguistic interpretations of the aesthetic element	26
4.3 Form embodied in text, drawing and tactile aspects	27
4.4 Positive correlations of designers' perceptions	27
4.5 Manual interpolative exercises complementary to automated CAD morphing	30
4.6 Representational content in relation to form structure and form meaning based on the PPE framework	30
<b>5. Summary of papers</b>	<b>32</b>
5.1 Paper 1 – The “old masters” of engineering design and the modern form development process of automobiles	32
5.2 Paper 2 – On the role of <i>formgiving</i> in design	33
5.3 Paper 3 – The embodied mind in relation to thinking about form development	34
5.4 Paper 4 – Designers' perceptions of typical characteristics of form treatment in automobile styling	34
5.5 Paper 5 – Understanding styling activity of automotive designers: A study of manual interpolative morphing through freehand sketching	36
5.6 Paper 6 – The significance of form elements: A study of representational content in design sketches	37
<b>6. Discussion</b>	<b>39</b>



6.1	Formgiving in relation to future automotive design education and practice	39
6.2	Design thinking and reasoning within the context of automotive design education and practice	40
6.3	Evaluation, verification and validation	41
6.4	Further work	42

**7. List of references 44**

**8. Appended papers 49**

Errata	50
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**Paper 1**

Abidin, S.Z., Sigurjónsson, J., & Liem, A. (2008). The “old masters” of engineering design and the modern form development process of automobiles. *Proceedings of the Design 2008, 10<sup>th</sup> International Design Conference, Dubrovnik-Cavtat, DS48-2*, 1199-1206.

**Paper 2**

Abidin, S.Z., Sigurjónsson, J., Liem, A., & Keitsch, M. (2008). On the role of formgiving in design. *Proceedings of E&PDE 08, 10<sup>th</sup> International Conference on Engineering and Product Design Education - New Perspective in Design Education, Barcelona, DS46-1*, 365-370.

**Paper 3**

Abidin, S.Z., Bjelland, H.V., & Øritsland, T.A. (2008). The embodied mind in relation to thinking about form development. *Proceedings of NordDesign 2008 Conference, Tallin, DS50*, 265-274.

**Paper 4**

Liem, A., Abidin, S.Z., & Warell, A. (2009). Designers’ perceptions of typical characteristics of form treatment in automobile styling. *Proceedings of Design and Semantics of Form and Movement, 5<sup>th</sup> International Workshop on Design & Semantics of Form & Movement (DeSForM 2009), Taipei*, 144-155.

**Paper 5**

Abidin, S.Z., Warell, A., & Liem, A. (2011). Understanding styling activity of automotive designers: A study of manual interpolative morphing through freehand sketching. *Proceedings of ICED 11, 18<sup>th</sup> International Conference on Engineering Design, Copenhagen, DS68-9*, 357-366.

**Paper 6**

Abidin, S.Z., Warell, A., & Liem, A. (2010). The significance of form elements: A study of representational content in design sketches. *International Journal of Design and Innovation Research*, 5(3), 47-60.

# 1. Introduction

## 1.1 Automotive Design

Automotive design partly deals with the visual appearance of vehicle exteriors (see Tovey, 1992). The perception of the vehicle depends heavily on the design produced by a designer. Established research on product experience provides a conceptual understanding of design. The challenge for automotive designers is to use his/her experience to make sure the appearance of the vehicle fulfills several requirements, such as those of the users, those related to market and sales, technologies changes, etc. In this process, the issue of product semantics and semiotics becomes more important in the development of automobile design. Based on Lloveras et al. (2004), product semantics and semiotics can be said to refer to user-object interaction; factors affecting user perception, meaning and messages in products and their designs; symbolic and iconic representation and interpretation; and psychological responses to objects.

With respect to the emphasis on the exterior development of a vehicle, definitions of automotive design, aesthetic development, and styling will be addressed in the next paragraphs to provide a framework for my research.

### *Definition of automotive design*

Much of the research on automotive design interprets the definition from a perspective of industrial design which concentrates mainly on seeing the designing by the stylist of the appearance of new products in the light of a general consideration of conceptual design (see Tovey, 1997, p. 10). However, in this thesis the definition of automotive design concentrates on the field of automotive design whose purpose it is to develop the visual appearance (exterior design) or aesthetic aspect of the vehicle while also considering engineering and business constraints, such as technical package, hard points, platform requirements, category, portfolio considerations, etc.

According to Clements and Porter (2006), automotive design is the consideration of aesthetics during the product development of an automobile. This consideration extends to all areas of the product readily visible to the customer: metal, glass, wheels, lamps, mirrors, grilles, badges and other adornments on the exterior, and all items of visible soft trim; seats, door trims, instrument panel and controls; steering wheel, switches, radio, console, etc. on the automobile interior. Visible design is generally considered to be one of the most powerful contributors to the branding and marketing of a vehicle (Karjalainen, 2004).

### *Definition of aesthetic development and styling*

Aesthetics is a branch of philosophy that deals with the nature of beauty, art, and taste, and the creation and appreciation of beauty (see Merriam-Webster, 2006). Scientifically, it can be defined as the study of sensory or sensory-emotional values, sometimes called judgments of sentiment or taste (Zangwill, 2003). According to Crilly (2005), the term is now most commonly used to imply visual appearance and is often restricted to the discussion of perceived attractiveness. Moreover, the word aesthetics may refer either to the qualities of an object or the quality of a perception. Aesthetics explores new ways of seeing and of perceiving the world. The designer uses their skills in applying aesthetic treatment to the development of

form to enhance the “appeal” factor of a product or vehicle. For example, the choices made in relation to the body of a new car are strongly based on criteria such as “beautiful” or “ugly”, and not only on technical criteria such as low air resistance and transportation efficiency (Pahl & Beitz, 1996). These choices are primarily made by the stylist in the design process.

Pahl and Beitz (1996) recognized the role of styling, and of the stylist as a specialist in the process of developing engineering design. Complementary to their work, Tovey (1997) has described the importance of styling in the automotive development process, where car stylists use intuitive processes, “private” form (i.e., the designer’s individual interpretation) and graphic languages (i.e., the designer’s visual linguistic interpretation), while design managers control the styling process through a number of management intervention points which provide a precise objective framework for the process. In this context, contradictions between designer and design manager in relation to decisions on form may become an issue once design interpretations are subjective.

## **1.2 Form Development in Automotive Design**

In this section, “the character of form” will be discussed in conjunction with challenges related to structuring its outcome as well as the creation processes involved. More specifically, the discussion asks whether form development is a planned process which mimics a structured problem-solving process in designing, or whether it is a reflective design activity in which the designer continuously engages in a kind of conversation with the “materials” in a certain “context.”

### ***The character of form***

In this thesis “form” refers to the visual appearance of automotive design. There are many interpretations of what constitutes the problem of form creation, and the interpretation depends to a great extent on the designer who produces it. Designers employ several approaches in the form development process (Tjalve, 1976; Muller, 2001). However, in current design practice, it is hard to standardize “form” or to generalize what constitutes form in any all-inclusive manner. This is because the design-related knowledge differs greatly from one designer to another. The designer’s perceptions depend on his/her background training, such as whether it is within art or science. Furthermore, while designing a product, interpretations of the characteristics of form are subjective in nature. These interpretations always depend on the use of form language, defining meaning (semantic aspects), facts (pragmatic aspects) and structure (syntactic aspects).

### ***The challenges of standardizing form***

Design is a central factor for the success of the product. The main issues relating to the perception of form and the perceived problems of form depend heavily on the interpretation of its character. The interpretation of the character of form varies from one designer to another, especially in terms of designers’ understanding of form characteristics related to gestalt (Monö, 1997). In automotive design, this includes several factors, such as visual elements (or form elements, in other words), form features, and components (see Warell, 2001; Karjalainen, 2004). The visual elements are point, line, shape/plane and volume. Features of form are, for example, accelerate line, hollow, concave, convex, etc. Components are elements such as headlamp, radiator grill, bumper, fender, etc.

In the automotive design process, the designers designing of form is considered an evolutionary process, and the concepts of “default” and “surprise” are part of their problem/solution spaces (see Dorst & Cross, 2001). Thus their contributions to the design depend on the implicit beliefs and attitudes of the designers. This can be contrasted to a view of the problem-solving design process as more structured and explicit.

As “form development” is skills driven and implicit, and cannot easily be made explicit, determining how form patterns can contribute to innovative and challenging form transformations in automobile design related to meaning, fact and structure represents an important challenge.

To identify what the understanding and development of form really involves, design research on manual interpolative morphing will be emphasized in this study, which explores how human design input can assist automated CAD morphing in the creation and development of form.

### ***The complexity of form development in automotive design***

The complexity of form is based on its level of abstraction (see Andreasen, 1991). According to Andreasen (1991), there are three levels of abstraction related to form in design: abstract, semi-concrete and concrete.

In automotive design, the most complex part of creating form is at the early stage. This is the most abstract stage, during which the idea is fuzzy in nature and everything depends on the designer’s experience, subjective interpretation, and influences from other objects and contexts. However, the climax of the activities usually occurs at the middle stage, when the idea is lifted to the semi-concrete level. During this stage, the designer goes through a process of exploring form, addressing form in relation to certain dimensions of representation. This process of form explorations and transformations then transcends to a concrete level where the elements of persuasion and design intent are emphasized. Although not part of the focus of this study, persuading the audience who will be interacting with and experiencing the product is part of the challenge at this stage.

In terms of visualization and representation, many techniques are used independently or in combination with other techniques throughout the various stages of typical design processes. However, from a manual designing perspective, freehand sketching is mostly preferred by automotive designers, as there are very few barriers to expressing new ideas and forms using the medium of “paper and pencil”. However, physical clay and foam models facilitate the form development process.

This kind of iterative and reflective practice, where the designer engages actively with the situation and its materials is quite common in the design discipline (Schön, 1983). The designer expresses form ideas based on mental images through several developments using thumbnail or detailed sketches. Since the sketches are languages for handling design ideas, the actual process of creating design ideas is usually envisaged as taking place in the designer’s mind, and the drawings are considered a reproduction of the designer’s mental images (Tovey, Porter, & Newman, 2003, p. 139).

Complementary to manual designing, Computer Aided Design (CAD) and Automated Morphing Systems (AMS) have become more important recently since it has been demonstrated that they can produce more gradual transformations from one image to another. Part of the aim of this study has been to observe and compare

the differences between a computer versus a designer in terms of how they gradually develop and evolve the design of a car using morphing techniques.

### ***Visual language and communication of form***

Designers use visual language to communicate about form in automotive design. Karjalainen (2004) writes that in the industry, designers talk about hard muscles under soft flesh in order to describe the forms and shapes of cars. This kind of visual language is commonly used in relation to styling activities.

In styling activities, automotive designers prefer to communicate using visual language to illustrate the characteristics of form, translating them into verbs and adjectives which represent its meaning (see Karjalainen, 2007; Warell, Fjellner & Stridsman-Dahlström, 2006b). The element of representation is described in relation to form as it translates from visual ideas to verbal expressions and drawings. It seems that the representations of form are embodied and sometimes hard to understand for other disciplines since the communication process involves classification of many non-technical elements.

In automotive design communication, designers usually relate form to certain aesthetic characteristics derived from nature or the artificial environment (Tovey & Porter, 2002). A good example is the attribution of permanent animal and non-human features to certain form characteristics of the car. Animal features can be explained as zoomorphism, and non-human features can be explained as anthropomorphism. The details of this were explained in paper 2.

## **1.3 Visualization and Representation in Form Development**

### ***Visual reasoning and normative aspects in design***

Designers commonly use visual elements as a basis for reasoning when expressing their creativity in design processes. Theoretically, visual reasoning emerges from a cognitive thinking process related to design (Oxman, 2002). In the visual representation related to form development, the way in which design thinking operates through externalized representations is visual reasoning.

In the theory of reflective practice, Schön (1983) regards normative design thinking as a basic quality of professional practice. The elements are interdependent and take place as a “reflection-in-action.” Schön’s concept of framing remains a useful account of the normative aspect of design thinking. Schön and Wiggins (1992) have investigated kinds of seeing and their relationship with the design activity. They regard designing as a conversation with materials conducted in the medium of drawing, and crucially dependent on seeing. It is characterized as a reflective conversation with materials whose basic structure-seeing-moving-seeing-is an interaction between designing and discovery. This basic model shows the designer visually interacting with symbolic representations of the material of the problem relating to design thinking through drawing and sketching. Designers draw on paper, observe the evolving product of their work, employ different kinds of seeing (visual apprehensions, literal seeing), and during these processes discoveries are made. Features and relations are identified which cumulatively generate a more complete understanding of, or ‘feel for’, the configuration with which the designer is working. They conclude that this involves giving attention to a process that computers are at present unable to produce.

In the discipline of automotive design, the concept of “normative” seems to be fundamental to design thinking. Something that is “normative” relates to, or determines, norms or standards (see Gedenryd, 1998; Rowe, 1987). Normative rationales for action are based on evaluative judgments which justify beliefs, attitudes or actions regarding matters of knowledge, aesthetics or morality. In the social sciences, the assessment or judgments are based on norms and value found in a given society. Normative theories are often articulated as manifestos, ideology, dogma, styles, schools or movements. Normative propositions are often compared with positivist ones, which are independent and based on verification by empirical means – a distinction sometimes referred to as descriptive versus prescriptive or fact versus value.

### ***Perception and cognition***

In the area of cognitive psychology, Arnheim (1969) provides a general principle relating perception and cognition. According to Arnheim, perception is united with visual cognition and we must see this operative relationship as one in which ‘the cognitive operations are essential ingredients of perception itself.’ Furthermore, cognitive responses with regard to the visual appearance of the product can be classified into three categories, as (1) Aesthetic impression, (2) Semantic interpretation, and (3) Symbolic association (Crilly, 2004a). In the area of automotive design, the design thinking process is often private and difficult to put into words because the styling process is intuitive and holistic, as well as supported by a strong non-verbal culture (Tovey, 1992; Tovey, 1997).

### ***Representation of form***

The symbolic association of form in relation to its representation can be defined as the perception of what a product says about its owner or user, that is the personal and social significance (character, status, likings, etc.) attached to the design (Crilly, 2005). Recent studies have indicated that while drawing or sketching shapes, the experienced designer can reason about their properties, such as the functions or the implied activities that are represented by shapes (Oxman, 2002). This representation includes the domain of semantic (meaning carrying) qualities embedded in shape or form in design (Jun & Gero, 1998). The generation of semantic and syntactic qualities requires significant insight and sensitivity by the designer. Therefore, initiatives to consciously introduce representational issues in design and brand development are limited. This suggests that a greater awareness of the need to understand how features of automotive design are interpreted and perceived in design and branding exercises.

## **1.4 Aims and Objectives**

The overall aim of this research is to study how designers think about and develop form in automobile design with the objective of providing a “creative” framework to complement and enhance the predictive performance of CAD systems. Therefore, the following partial aims and objectives have been identified:

- (1) To understand how designers reason about the form that they generate;
- (2) To understand how exterior car designs have been influenced by preceding designs;

- (3) To understand which elements, features, etc. were influential in the generation of incremental or radical design changes with respect to preceding designs; and
- (4) To understand the characteristic differences between manual morphing and form generated by AMS (Automated Morphing Systems) and the implications.

## 1.5 Research Questions

The research questions were designed to uncover how designers generate forms driven by their implicit values, beliefs and attitudes towards designing, and how these are supported by their visualization and representation skills. The following research questions have been formulated:

- How do car designers generate exterior form through the interactions among their sketching activities and implicit/cognitive thinking patterns supported by their attitudes, values, beliefs, and contextual assumptions?
- How were exterior car designs influenced by preceding designs, and which specific elements, features, etc. were addressed in the generation of incremental or radical design changes with respect to these preceding designs?
- What were the differences in form development between Automatic Computer Aided Morphing and manual form generation conducted by designers?
- What are the meanings of elements and features that were manually and unexpectedly transformed by designers, and how do these relate to preceding designs?

## 1.6 Limitations

The limitations related to empirical data gathering were concerned with finding a suitable number of practicing car designers who were prepared to actively take part as subjects in extensive observational studies, and willing to complete two sets of questionnaires. This led to the engagement of designers with a wide variety of knowledge, skills and experiences as subjects in this research project. The fact that the subjects had such different backgrounds (*students, novice designers, intermediate designers, senior designers, and expert designers*) – and the different levels of knowledge and skills this implied – needed to be considered in the analysis of results.

Students, novice designers and designers in intermediate positions were very cooperative. However, it was harder to gain the cooperation of senior and expert designers. They seemed to have reservations about demonstrating their skills. The reason could be that they had lost their core design skills, since they have moved up the career ladder to management positions where they were no longer actively involved in designing.

Another limitation was the difficulty encountered when seeking to re-engage the same subjects (car designers) in follow-up research activities, such as classifying overall car designs, features and elements according to their type of representation. The main reasons here were that the time and budget constraints preventing, as well as the fact that the subjects have dispersed and moved on in their careers.

## 1.7 Thesis Structure

This thesis is constructed as follows:

Chapter 2: *Frame of reference*

Chapter 3: *Methodology*

Chapter 4: *Results*

Chapter 5: *Summary of papers*

Chapter 6: *Discussion*

Chapter 7: *List of references*

Chapter 8: *Appended papers*



## 2. Frame of Reference

This chapter describes the framework of the research. The variables selected are structured within this framework, and their connection will be explained within the context of three interconnected practice related fields: Form Structuring and Development, CAD and 3-D Modeling, and automated morphing systems.

### 2.1 Syntactic, Pragmatic and Semantic Issues related to Form Development

In design thinking, the creation and development of form is commonly regarded as a result of body and mind interaction as part of the affective domain. The affective domain includes the manner in which we deal emotionally with matters such as feelings, values, appreciation, enthusiasm, motivation and attitudes (Krathwohl, Bloom, & Masia, 1973). The five major categories of this domain range from the simplest behavior to the most complex: receiving phenomena, responding to phenomena, valuing phenomena, organizing and internalizing values. In terms of this domain and design, a designer uses his/her imagination in a metaphorical way to visualize an idea. According to Lakoff and Johnson (1999), metaphorical form is embodied in the thinking about form. Findings of cognitive science are profoundly disquieting in two aspects, as (1) Human reason is a form of animal reason, and (2) Our bodies, brains, and interactions with our environment provide the mostly unconscious basis for our everyday metaphysics, that is, our sense of what is real.

According to Lakoff & Johnson (1999, p. 17), “Our sense of what is real begins with and depends crucially upon our bodies, especially our sensorimotor apparatus, which enables us to perceive, move, and manipulate, and the detailed structures of our brains, which have been shaped by both evolution and experience”. Metaphors allow conventional mental imagery, to be used in the domains of subjective experience.

#### *Syntactic issues*

Form syntactics deals with the structure and composition of visual elements (Warell, 2001). Broadly, it involves the analysis of a product’s technical construction as well as the analysis of visual details such as joints, openings, holes, crossing forms, texture, graphics, etc (Vihma, 1995). In the design world, the uses of this terminology refer to the visual form aspect of a product. The existing model of design syntactics consists of two basic concepts, namely *form elements* and *form entities* (Warell, 2001). Form elements can be related to material-physical and configuration issues, while form entities deliver syntactic and semantic functionality to the product form.

Laws of form can be explained in terms of structured or controlled and unstructured or uncontrolled. The objects which have one fundamental property of form are a shape, a certain arrangement of parts, and an overall structure. According to Tjalve (1976), form may arise in four different ways, as (1) An uncontrolled process, where the form depends solely on the conditions of the environment, e.g., pebbles, mountain ranges; (2) A process controlled by physical and chemical laws as well as the conditions of the environment, e.g., ice crystals, mica; (3) A process controlled by genes and the conditions of the environment, e.g., living organisms; and (4) A process controlled by the wishes of men or animals and

the conditions of the environment, e.g., manufactured products, a beaver's dam, a bird's nest.

In industrial design, the creation of form(s) while designing involves an understanding of how to use basic *visual elements* such as point, line, plane or surface, and volume (see Figure 1), as well as the rules and principles governing the organization of the composition or structure (Akner-Koler, 2000). Visual elements are part of the attributes of form that create tone and texture, thus imparting visual interest and meaning. Their importance becomes evident through their use in generating images and form(s) that are both two-dimensional and three-dimensional.

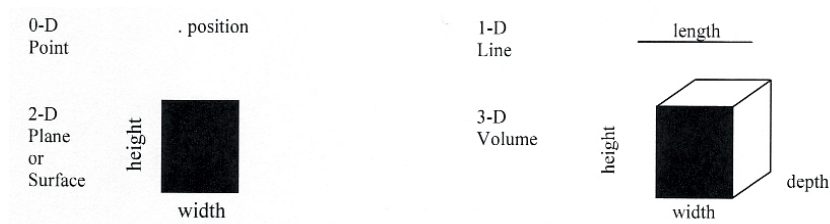


Figure 1. Four basic visual elements (Akner-Koler, 2000, p.7; Muller, 2001, p.80)

According to Wallschlaeger and Busic-Snyder (1992), defining and relating the application of visual elements to visual studies can sometimes be very challenging since the term(s) can be interpreted and used in different ways, not only in art and design but also in other disciplines, especially engineering, mathematics, physical sciences, and humanities. To give a clearer picture, a mathematician may think about defining words such as point, line, plane or surface, and volume in abstract terms. However, in geometrical terms, a point has no dimension. It is only used to define a location or position. A line is conceived as a point in motion within space, which has only one dimension length. A plane or surface is a flat surface bound by lines that has the attributes of length and width, but no depth. Volume, in conceptual terms, is described as a plane in motion in a direction other than its inherent direction. For example, a 3D form is derived from and enclosed by planes that have a position in 3D space.

According to Gestalt theory (King & Wertheimer, 2005), the perception of Gestalt is central in the appreciation of visual appearance in design. Gestalt is an arrangement of parts which appears and functions as a whole that is more than the sum of its parts (see Monö, 1997). The quality of the whole as being more than the sum of its parts means that the way forms, colors, and materials are combined and structured generate a holistic value addition, usually referred to as a product or system. When this has occurred, its parts are no longer treated as isolated characteristics.

**Pragmatic issues**

Form in terms of pragmatic issues is concerned with facts and actual occurrences or practice. Most of the approaches used in engineering design are pragmatic in nature. In automotive design, examples of design based on pragmatic approaches can be seen in the development of an Excavator and Road Roller (see Tjalve, 1976; Hubka, Andreasen, & Eder, 1998). These approaches focus on a quantified structure, where problem solving and dissection are related to the generation of

principle solutions during the conceptualization phases. The well-known “old masters” of engineering design who have used these approaches, are Pahl and Beitz (1996), Hubka (1982), Tjalve (1976), and Roth (1989). Details of these approaches are discussed in paper 1 of this thesis.

Furthermore, in engineering design, the creation of form(s) can be based on several form-generation models. Many of these models are based on *principle solutions*, such as the problem-solving process (Simon, 1961), and synthesis–analysis order (Sim & Duffy, 2003). The problem-solving process is an activator assisting in the creative process that in a general sense encompasses a variety of activities with widespread applications (Pahl & Beitz, 1996). This process is either structured or unstructured, and can also result in the generation of form(s). The problem-solving process also considers the design activity as a problem to be solved (Simon, 1961). Simon (1969) described problem solving as one of the strategies in design development. The use of the method of quantified structure (Tjalve, 1976) or quantitative structure (Muller, 2001) is common in engineering design, and especially in the creation of form, because it involves the element of problem solving. Tjalve (1976) states that quantified structure is chosen based on two different viewpoints, dependent on whether or not the functional connections between the elements can be included. If these functional connections are ignored, the structure variation method gives a number of suggestions for a very general construction of the product. If the functional connections are included, suggestions for further development of the basic structure will be made, with the aim of optimizing and specifying the parameters involved.

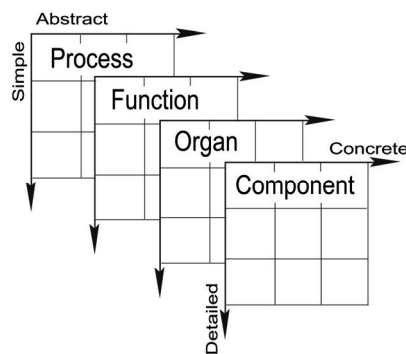


Figure 2. Models of technical systems are organized in four domains, along the two dimensions of abstract to concrete and simple to detailed (Andreasen, 1991; Buur, 1990; Øritsland, 1999)

A similar way of facilitating pragmatic and structured problem solving is through the use of “technical systems”. In the theory of technical systems, there are four domains of designer works, based on level of abstraction. The domains are: (1) The domain of processes; (2) The domain of functions; (3) The domain of organs; and (4) The domain of components (see Andreasen, 1991). Andreasen (see Figure 2) proposes a model for the causal relationship between the different domains of machine systems: (1) between Process and Function: The technological principle for the transformation which is the purpose of the machine determines the functions which are to be implemented by the machine; (2) between Function and Organ: Functions are created by the organs within the machine. Organs at a high level can

make it necessary to implement new transformations, which in turn leads to second-order functions and organs, and so on; and (3) between Organ and Component: Organs are materially implemented by machine parts. The necessary relationship between machine parts may lead to a requirement for low-level organs such as joining, connecting and support organs, which in turn lead to a requirement for new machine parts.

Quantified structure does not deal with the aesthetic features, however, because intuitive form creation is an emotional and cognitive process, which is, firstly, driven by the inherent knowledge, past experiences, and prevailing assumptions of designers, and, secondly, stimulated by the designer's interaction with the material in its context. Here the hermeneutic model for designing (Darke, 1979) can be used as a reference. Synthesis-analysis is considered here as a compound activity, as it involves search, exploration and discovery of design solutions, and composition and integration of these solutions (Sim & Duffy, 2003).

However, quantified structures and cognitive subjective process are equally important in the generation of car designs. Muller (2001) has suggested three levels of form development which are commonly used in the automotive design discipline. The first level is topological. At this level the designer's task is exploratory, and he or she thinks in a metaphorical, analogue, and behavioral manner, because the effect or artifact and properties are still only fuzzy ideas. Industrially, everything is still in the conceptual phase. The instruments used at this level are texts, drawings, and pictures. The Convergence level of the composition or decomposition is basically conceptual. On the other hand, the level of abstraction is purely abstract.

The second level is the typological level. At this level, the designer's task is explanatory. The designer's thinking is geared towards the surface, and the geometric and organic order. The effect or artifact and properties are extensional. Industrially, things have moved on to the developmental phase, and instruments are used in a form of drawing. The Convergence level of the composition or decomposition is represented by layout. The level of abstraction is semi-concrete.

The third level is the morphological level. The designer's task is now very much a matter of persuasion. The ways designers think are influenced by the systems of arithmetic and semantic order. The effect or artifact and properties are superficial. The industrialization has reached the product intent and/or preparation phase. The instruments used are drawing and CAD. The Convergence level of the composition or decomposition is very detailed. The level of abstraction is concrete.

In terms of measuring and documenting form creation in design from an industrial art and design perspective, qualitative measurement is the preferred way of documenting the design findings (Akner-Koler, 2000). Meanwhile, from an engineering design technology and engineering perspective, quantitative measurements are common (Muller, 2001). A detailed explanation of quantitative and qualitative structures is provided in paper 1 and 2 of this thesis.

### ***Semantic issues***

In styling design, "semantics" covers commonly used terminologies. Semantics is a study of meanings (Merriam-Webster, 2006) and in the design world it is normally associated with "semiotics." Semiotics is the study of signs and sign systems, their structure, properties and role in socio-cultural behavior (Monö, 1997, p. 58). The term "semantics" is closely related to the study of the meaning of signs (or semiotics, which is a more general term). In other words, semiotics considers how

forms communicate meanings through signs – such as when a coffeemaker communicates that it belongs to the world of kitchenware through its general form and white color. Another example is illustrated in Figure 3, where a form element, namely the side-shoulder, also known as the “cat walk”, communicates a structural function of increased strength and improved aerodynamics and carries important aspects of the semantic and syntactic functionality of the Volvo form language (see Warell, 2001).

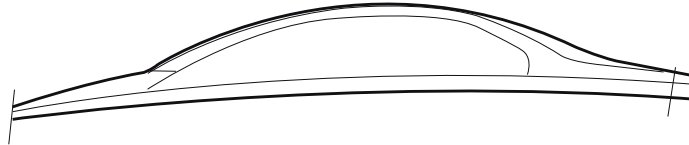


Figure 3. The side-shoulder, also known as the ‘catwalk’, carries semantic and syntactic functionality as part of the Volvo form language (see Warell, 2001)

Meaning thus depends on the qualities of the interpreter. Moreover, signs are not necessarily visual. Any type of perception of a product can induce meaning – be it sound, feeling, smell or taste. Such meanings can have a great influence on innovation, because of their power of representation, their ability to create identity, and possibly even to influence the course of technological development. According to Krippendorff (1989, p. 12), meaning is a cognitively constructed relationship. It selectively connects features of an object and features of its (real environment or imaged) context into a coherent unity. The reasons for such relationship are numerous. Engineers and ergonomists have almost exclusively settled on functions, on measurable, causal connections that are manifested in the push and pull of controlled physical forces. Although functional accounts (including semiotically informed “stand-for” relationships) are undoubtedly meaningful to some, ordinary people also employ many non-causal relationships – such as similarities, contrasts, family belongingness, associations, synchronicities, harmonies, or social conventions – to relate objects to their environments. However, the perception of how something fits into a cognitively constructed context has no causal foundation. What something is (the totality of what it means) to someone corresponds to the sum total of its imaginable contexts. Krippendorff (1989) also suggested that “Making sense is a circular cognitive process that may start with some initially incomprehensible sensation, which then proceeds to imagining hypothetical contexts for it and goes around a hermeneutic circle during which features are distinguished – in both contexts and what is to be made sense of – and meanings are constructed until this process has converged to a sufficiently coherent understanding”.

Vihma (1995, p. 85) wrote about the cultural context of products. She stated that it is only meaningful to interpret the signs conveyed by a product within a cultural context. Therefore, one can “...interpret a car as a semantic entity when it is put into relation to other means of transport, such as other cars, bicycles or trains, and to other ways of traveling and moving, for example, a pedestrian and driver.” The features that a car has in common with other cars, as well as those which distinguish it from other cars, define the car in a culture and as a part of a “semantic field”. For example, in the car model Volvo S60, specific shapes are used to refer to the characteristics of the Scandinavian design heritage (Karjalainen, 2007). Thus, the gestalt (form, colors, composition, etc.) of a product does more

than just please or displease the eye – it places the product in a cultural context of different signs, which in turn are the building blocks of the semiotic language related to the product. Vihma refers to a model created by Gros (1983), which incorporates both the practical and the aesthetical functions of a product. The product functionality is considered a relationship between product and user. Practical functions are associated with the ability of the product to function in practical use. Product language functions refer to the appearance of the product, and are of two types: sign functions on one hand, and formal and aesthetic functions on the other. Sign functions are carried by semiotic signs. They refer to functions, properties, qualities and characteristics, etc. Semiotic signs can indicate factual information about the product's use and properties, and symbolize qualitative information dependent on subjective personal and cultural interpretation. In Gros's model, the formal and aesthetic functions are of a non-semantic nature and connected to the visual-aesthetic content of the product. Other studies have also attributed meaning to formal and aesthetic functions (see Muller, 2001; Warell, 2001).

Within the contextual relationship of how designers think about and create form, a standpoint has been taken that each individual designer has his own design style. For example, in my video observations, I asked designers to morph from one vehicle to another (see Papers 5 and 6). The designer morphed gradually but only transformed a few selected parts of the car. This implies that in the form transformation process, contexts, values and beliefs were implicitly considered by the designers, and only communicated explicitly only through abrupt unexpected “form variations.”

## **2.2 Model of Experience**

As this work is concerned with designers' perceptions of emerging representations (such as sketches) of products, it is essential to be able to assess the sketches in relation to some type of conceptual understanding of relevant perceptions. The purpose is to identify a suitable framework for analyzing designers' sketches with respect to relevant but different ways of experiencing such sketches. Multiple frameworks and models which describe product experience exist in the relevant literature. Hiort af Ornäs (2010) described 6 models of experience that were commonly used in design research (see Norman, 2004; Desmet, 2002; Desmet & Hekkert, 2007; Jordan, 2000; Nagamachi, 1995). These included (1) Kansei Engineering, (2) Basic model of product emotions, (3) Framework of product experience, (4) The emotional design framework, (5) The four pleasures framework, and (6) Model of user experience. In the following, three models which have been considered in this research are presented.

Several authors (see, e.g., Monö, 1997; Crilly et al., 2004b) have adopted the transmission model of communication, originally proposed by Shannon and Weaver (1949), as a way to describe how products communicate with users. In Monö's model (see Figure 4), messages are encoded into the product by the designer (the sender). These messages are carried by the physical product gestalt (the combination of form, color, texture, structure, etc.), and eventually decoded by the user (the receiver of the message). Monö proposes that four types of semantic functions (describing, expressing, exhorting, identifying) form the basis for the communication of meaning between artifacts (and their representations) and users.

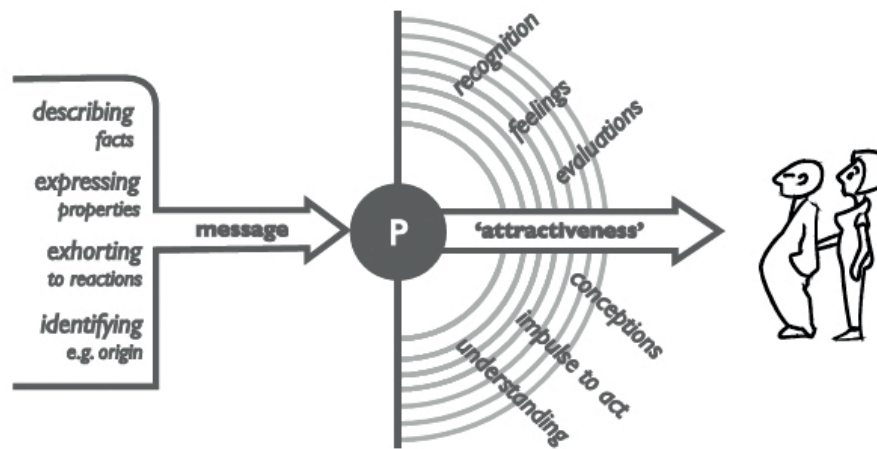


Figure 4. Monö's (1997) model of the communication process, based on Shannon and Weaver (1949)

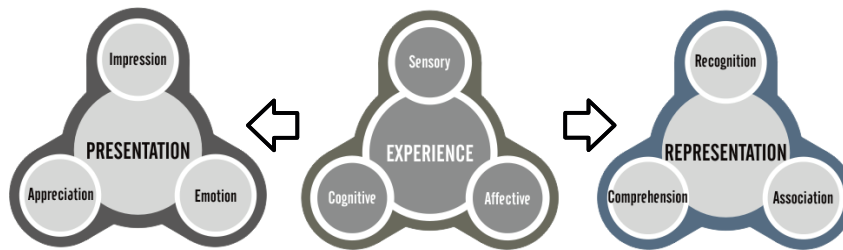
Crilly et al. (2004b) expand the understanding of the nature of the communication by proposing that consumer response to product form is divided into cognition, affect and behavior. Here, cognition consists of aesthetic impression, semantic interpretation, and symbolic association, while affect includes emotional response, and behavior refers to users' tendencies to approach or avoid, based on how the product is experienced.

Hekkert (2006, pp. 159-160) suggested that product experience can be defined as "the entire set of effects that is elicited by the interaction between a user and a product, including the degree to which all our senses are gratified (aesthetic experience), the meanings we attach to the product (experience of meaning) and the feelings and emotions that are elicited (emotional experience)." These three components or levels of experience can be distinguished as they all have their own, albeit highly related, law-governed underlying processes. Furthermore, Hekkert states that they are "conceptually different, although they are intertwined and impossible to distinguish at a phenomenological level (ibid, p. 159)."

While these frameworks provide a conceptual basis for understanding the nature of product experience, they offer limited support in the mapping or identifying of the actual experiences arising in product perception. For this purpose, the framework of Perceptual Product Experience (PPE) suggested by Warell (2008) has been useful. In the PPE framework, product experience is modeled as a phenomenon composed of three core modes: the sensorial, cognitive, and affective modes of experience; and two dimensions: presentation and representation (see Figure 5). Hence the framework recognizes that the experience consists of components which are perceived directly through the senses, as well as components which require interpretation, and thus are socio-culturally and contextually dependent.

The three core modalities recognize all possible types of perceptual experience, including initial impression and recognition of the product's existence and its specific perceptual characteristics (the sensorial mode); making sense of the product: its manifestation, structure, use, origin and purpose (the cognitive mode);

and the affective response: attribution of value to, and judgment of the product (the affective mode).



*Figure 5.* Framework of perceptual product experience (PPE framework), with core modes (centre), the two dimensions of presentation (left) and representation (right), with submodes (Warell, 2008)

The dimension of presentation is concerned with the direct, sensual stimuli-related side of the experience. In short, presentation may be seen as the ‘pleasurable’ side of the experience, related to the direct, non-interpretative experience, and includes the impression, appreciation and emotion submodes.

In this thesis, I am interested in the significance of form elements as interpreted by designers. The dimension of representation regards the product experience as a meaning-making phenomenon that can be described by the three submodes of ‘recognition,’ ‘comprehension,’ and ‘association,’ which can be explained through Peircean sign theory (Peirce, 1931-1966). When seen in the light of the identity references for each sub-mode, it becomes clear that the representation dimension is intimately related to product identity (Warell, 2006a; Warell, Fjellner, & Stridsman-Dahlström, 2006b):

- Recognition (of Type): “What the product is” (function, use, purpose, make)
- Comprehension (of Characteristics): “How the product is” (properties, performance, behaviour, mode-of-use)
- Association (to Values): “What the product stands for” (origin, brand, heritage, culture)

Consequently, a product with strong representational qualities in all three submodes will most likely be perceived as having a strong and clear identity.

This framework is beneficial to my research as an aid to determining the significance of elements and features which were manually and unexpectedly transformed by designers, compared to preceding designs.

## 2.3 Computer Aided Design and Modeling Systems

Computer Aided Design (CAD) tools are today widely established support tools which greatly facilitate the design process. CAD was used to create and list the representations based on concrete data. CAD is used in styling in areas such as form morphology, geometric transformation, and interpolation. Several established car manufactures, especially in Japan, regularly use morphing systems in their research and design activities as an alternative way to study form development. It builds mainly on geometric algorithms that assist designers in heuristic decision making (Wang, 1995).



In the automotive design industries, CAD is currently used primarily to support the manual form development process and to produce technical data for further use in the engineering and manufacturing processes (Lee et al., 1994). In the design world, there are numerous variations of CAD modeling systems, ranging from low-end to high-end usage. The choice of modeling system is heavily dependent on the expectations of stakeholders and end-users in terms of product and presentation qualities.

The central problem with the application of CAD is that it adopts a quantified structural approach towards creating and designing, and therefore does not consider the qualitative aspect of the affective domain (i.e., feelings, perceptions, etc.) designers bring with them into the design process. Recently, the CAD software platform, especially morphing for design purposes, can be found as both two-dimensional (2D) and three-dimensional applications (3D).

#### ***Two-dimensional CAD morphing***

In two-dimensional CAD, many different terms are used for form development, such as transformation, evolution, mutation, morphing, etc. Within the context of visual and explicit morphing, human facial transformation, which is similar to form transformation in automotive design, has provided useful references. Beier and Neely (1992) demonstrated 2D morphing between two images with manually specified corresponding features such as line segments. They noticed that it was difficult to synthesize realistic head motions since target features are revealed during the transformation process, especially in animation. Chang and Jenkins (2006) propose a 2D sketch interface for posing 3D faces. In their work, users can intuitively draw 2D strokes in 2D face spaces that are used to search for the optimal pose of the face.

In terms of the exterior design of automobiles, 2D CAD has been recognized as the easiest way for automotive designers to develop and morph form in design. This is because it is freeform, flat and limits the number of technical issues to be considered at this point of the development. However, the advantage of designing and morphing in a 2D surface framework is that the designer is able to control the structure as well as the quality of form. For example, a type of 2D software for morphing and animation purposes in common use is Animator, a micro computer-based 2D animation system developed by Autodesk (Wang, 1995).

#### ***Three-dimensional CAD morphing***

In order to overcome the limitations of 2D morphs, Pighin et al. (1997) combined morphing with 3D transformations of geometric models. They animated key facial expressions using 3D geometric interpolation. However, animations are still limited to interpolations between predefined key facial expressions. Based on a blend-shape representation for 3D face models, Joshi et al. (2003) proposed an interactive tool to edit 3D face geometry by learning controls through physically motivated face segmentation. A rendering algorithm for preserving visual realism in this editing was part of their proposal.

Designers use 3D CAD so that the form of the design better meets the designer's design expectations. The process is quite complex since it involves technical preparation and considerations. These need to be emphasized since they involve surface and solid modeling (Wang, 1995). The common software applications used for three-dimensional CAD in automotive designs are Alias and Catia. However, for morphing and animation purposes, software such as Elastic

Reality by MorphPlus, Gryphon Software Morph on Macintosh, ImageMaster, and CineMorph is used and has often proven to be more practical.

#### ***CAD modeling systems relating to form development***

Currently, there are several software packages that have been developed for the CAD modeling system. One of the most widely used is the Automated Morphing System (AMS). AMS allows form developed based on the elements of quantitative structure (Wang, 1995). However, at the same time, many researchers have attempted to develop AMS software involving qualitative structure elements (Nagamachi, 1995).

Much research conducted on CAD modeling systems has attempted to address affective elements within the form development process. Among these attempts is Kansei Engineering (Nagamachi, 1995). Kansei Engineering (KE) focuses on product attributes and their relation to affective meaning. KE systems have been applied in research and development in the car industry as a numerical tool to define affective response in relation to design features. The development of the Mazda Miata car is an example where Kansei Engineering was used in product development.

## **2.4 The Concept of Morphing and Use of its Techniques**

The use of morphing techniques has been widely explored within the framework of form development and as a possible means to generate a wide range of alternatives. 'Morphing' is the gradual exploration of 'form' solutions/ideas which lie between two or more poles, represented by visual examples. Hence Automated Morphing Systems (AMS) is a powerful software tool for facilitating and generating visually compelling and fluid form transformations. These transformations are created by synthesizing intermediate images between the supplied image poles as well as by interpolating between certain common features in the initial and final images (see e.g. Hsiao & Liu, 2002).

#### ***CAD versus manual morphing***

Most of the previous work related to the use of morphing has been conducted with the support of CAD. CAD-based morphing techniques attempt to imitate certain aspects of the designer's work, that is, it performs certain routine-based and holistic design explorations once a main theme has been established. Two significant limitations are associated with CAD-based morphing approaches compared to the work of a designer. Firstly, CAD-based techniques can only employ an interpolative strategy for form generation, whereas the designer also uses extrapolative strategies. Secondly, CAD-based techniques only consider the geometrical transformation as such, and do not have the capacity to consider intentional creation of meanings.

Several approaches have been used in styling for geometric transformation through interpolation (see e.g. Lin, 1989; Zwicky, 1967; Chen, 1986). These employ a number of algorithms (procedures of calculation) which have been developed for image morphing (see Wolberg, 1990), such as linear and polynomial interpolation, and cubic splines with natural or periodic boundaries.

#### ***Interpolative and extrapolative strategies***

The interpolative strategy is to produce images which lie between two images, while the extrapolative strategy is to produce an image that extends ‘beyond’ one of the control images. In practice, the interpolative strategy is the most common approach in morphing. Many works on interpolative morphing are based on linear (Wolberg, 1998) and curve interpolation (Kerlow, 2008). The techniques for interpolation can be used to calculate the position of objects in space, as well as their shape and other attributes. Linear interpolation is the simplest and most straightforward technique for calculating in-between frames. However, linear interpolation cannot handle subtle changes in speed, especially in 3D animation, because the in-between frames are created at equal intervals along the path. Curve interpolation is a technique for calculating in-between frames that is more sophisticated than linear interpolation. Curve interpolation averages the parameters in the key frames, taking into account the variations of speed over time, known as acceleration.

Extrapolative strategies are non-linear and non-uniform (Chen et al., 2003). They are intuitive, based on human perceptions, and they have certain semantic characteristics.

#### ***Approaches and algorithm***

Wolberg (1998, p. 361) presents three approaches to morphing algorithms for the development of morphing and image transitions of linear interpolations that fade from one image to another. For example, within the context of AMS, certain facial image transformations of multiple images – such as eyes, ears, nose and profile – derived from four different inputs of images can be blended simultaneously through the following procedural steps: 1) Cross-dissolve; 2) Mesh warping; and 3) Multilevel free-form deformation (MFFD) based morphing. An example of MFFD-based morphing is given in Figure 6.



*Figure 6.* Multilevel free-form deformation based morphing (Wolberg, 1998)

With respect to MFFD, Rowland and Perrett (1995) considered a special case of *polymorph* to obtain a prototype face, in terms of gender and age, from several tens of sample faces. AMS has also been used for the kind of multiple image transformation which is known as *convex polyhedron* (Wolberg, 1998). Non-uniform blending has also been considered in volume metamorphosis to control blending schedule (Hughes, 1992; Lerios et al., 1995). The polymorph framework includes non-uniform blending of features in several input images (see Lee et al., 1998). In a polymorph the focus is on selected regions in several input images (Wolberg, 1998). The regions are blended together with respect to geometry and color.

Examples of morphing techniques supported by AMS include mesh warping (Wolberg, 1990), field morphing (Beier & Neely, 1992), radial basis functions (Arad et al., 1994), thin plate splines (Lee et al., 1994; Litwinowics &

Williams, 1994), energy minimization (Lee et al., 1996), and Multilevel Free-Form Deformations (MFFD) (Lee et al., 1995).

Within the context of form development in automotive design, the MFFD-based approach was used as an example for this study. In CAD systems, the MFFD technique for warp generation is simplified and applied to efficiently generate a  $C^2$ -continuous surface for deriving transition functions (Wolberg, 1998). The transition curves can be replaced by procedural transition functions (Lee et al., 1995).

## 2.5 Automated Morphing Systems (AMS) in Automotive Design

### *Shape averaging*

The research on shape averaging (Chen & Parent, 1989) is pioneering work within design interpolation. Shape averaging produces a series of novel shapes that fit between two typical shapes representing different meanings. It is hypothesized that average results are useful for predicting trends in form, or for extracting stereotypes from a group of related shapes. This technique can be useful for creating new forms in automobile design by blending general features of existing unrelated shapes.

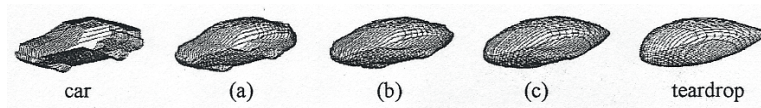


Figure 7. Weighted average shapes derived from a car and a teardrop shape, with ratios of (a) 70/30, (b) 50/50, and (c) 30/70 (Chen & Parent, 1989)

The algorithms of shape averaging can extract the mean, median and mode forms from the average shape (see Chen & Parent, 1989). Figure 7 shows the results of blending a car shape and a teardrop shape at differently weighted averaging ratios.

Complementary work by Hsiao and Liu (2002) facilitates shape morphing by analyzing the transformation of images from the percentage ratios of 0%, 25%, 50%, 75% and 100% on a parametric scale. In their study, Hsiao and Liu compared several methods, such as statistic regression, fuzzy evaluation, and gray theory. These morphing algorithms have been used as a foundation for car morphing in several design research projects studying form transformation in design.

### *Previous work on morphing related to automotive design*

In automotive design, predicting and establishing the relationship between product forms and how these product forms are perceived and felt, has usually been based upon two approaches, *inversion* and *interpolation*. The *inversion approach* attempts to establish an explicit relationship between attributes and perceptual qualities so that the given target values of perceptual qualities can be “inverted” to obtain the required settings of the attributes. The *interpolation approach*, on the other hand, attempts to obtain the desired settings of attributes implicitly, rather than explicitly, by “interpolating” objects with the desired qualities.

The inversion approach is essentially harder to manage than the interpolation approach because of the potentially large number of attributes required to fully specify a product. An example of the design inversion technique is

Kansei Engineering (Nagamachi, 1995), which uses statistical methods to obtain mathematical relations between product attributes and perceptual qualities.

However, most studies pertaining to automotive design capitalize on the interpolation approach, exploring form in relation to an affective element such as feeling, emotion, pleasure, etc. In order to understand how product shapes evoke affective responses, Chen et al. (2003) conducted a survey to evaluate the affective characteristics of product shapes connected to an analysis of product semantics. Semantics is an approach which describes users' emotional and cognitive requirements for a product, while also assessing whether these requirements have been incorporated in the respective product or product concept (Wikström, 2002).

A perceptual map of automobile shapes was constructed for the further study of relationships between automobile shapes and the affective responses they elicited. Nineteen representative automobiles and seven adjectives were chosen for analysis. A perceptual map was constructed using a multidimensional scaling program (MDPREF). A preference – mapping program (PREFMAP) was also used, in order to determine the location of the vector corresponding to each adjective in the perceptual map; see Figure 8.

In the perceptual map, the distance between points reflects similarities and dissimilarities. Thus, if two adjectives look similar, these two aspects will be positioned close to each other, whereas if two adjectives look dissimilar, the corresponding points will be further apart. Observing the perceptual placements of nineteen automobiles and seven adjectives, the researchers found that there are many empty spaces (indicated by dotted circular lines).

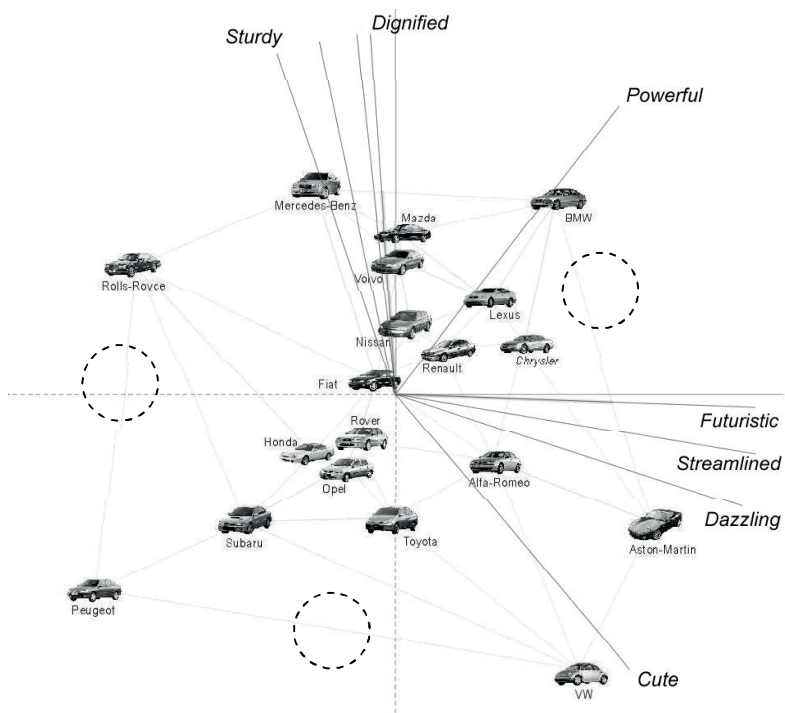


Figure 8. Perceptual map of 19 representative automobiles and 7 representative adjectives (Chen et al., 2003)

## 3. Methodology

### 3.1 Design Research Methodology

According to Cross (2006), the kinds of methods used for researching the nature of design thinking include: (1) Interviews with designers (see Lawson, 1994; Cross & Clayburn Cross, 1996); (2) Observations and case studies (see Candy & Edmonds, 1996; Galle, 1996; Valkenburg & Dorst, 1998); (3) Protocol studies (see Lloyd & Scott, 1994; Gero & McNeill, 1998; Cross et al., 1996); (4) Reflection and theorizing (see Simon, 1969; Schön, 1983); and (5) Simulation trials.

In this thesis, the research is exploratory in nature. The objective is to explore or search through a problem or situation in order to provide insight and understanding. Through my research papers, I have employed several methods in the present research. Among these research methods are content analysis (Papers 1 and 2), verbal protocol analysis (Paper 3), survey (Paper 4), and natural video observation and semi-structured interview (Papers 5 and 6).

These approaches provide two paths for conducting research, namely: (1) An empirically oriented approach based on observation and the subsequent production of theoretical statements, and (2) A theoretically oriented approach based on logical reasoning for attaining knowledge. This combination has similarities with the scientific method of the formal sciences. The two approaches used together also seem more capable of handling the great divergence between the nature of design research by means of empirical methods, and the design object approached. The two approaches cannot be fully separated however, since the “product and process dualism” of design work must be addressed in design research (Warell, 2001, p. 25). Also, this research takes into account two research strategy approaches, incorporating a combination of problem and theory-based research. Either analysis or synthesis may thus be the starting point for a work of research, but in practice, most research projects will involve both paradigms, albeit to varying degrees (Sigurjónsson, 1992).

The framework of this research is based on the stages of the Design Research Methodology (DRM) (see Blessing et al., 1998). The DRM emphasizes several factors: The need to formulate success as well as measurable criteria (for example, the role of the *Criteria* definition stage is to identify the aims that the research is expected to fulfill, as well as the focus of the research project); the need to focus *Descriptive Study I* on finding the factors that contribute to or prevent success; the need to focus the *Prescriptive Study* on developing support that addresses those factors that are likely to have most influence; and, finally, the need to enable evaluation of the developed support (*Descriptive Study II*).

The design research methodology framework shown in Figure 9 describes the development of product models for this research work. *Criteria* for the success of the research are derived both from theoretical statements (see Papers 1 and 2) and from observations of design practice (see Papers 3, 4, 5 and 6). *Description I* of the phenomenon studied constitutes the basis for a *Prescription*, which in turn affects the phenomenon (see Papers 4, 5 and 6). *Description II* shows this impact. Depending on the outcome, a better description of the phenomenon is achieved (*Description I* again), or a new *prescription* is formulated for the synthesis and problem solving of the design process.

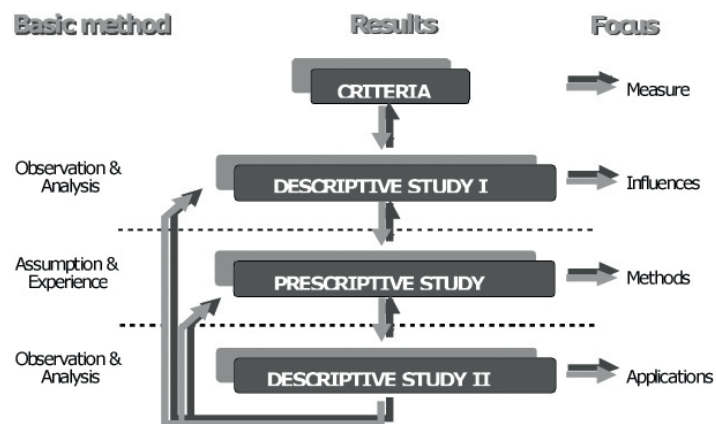


Figure 9. A Design Research Methodology framework (adapted from Blessing et al., 1998)

Design research methodology is derived from knowledge produced through design research, scientific research on design, cognitive psychology, and practical experience (Pahl & Beitz, 1996).

### 3.2 Research Approach

This research was carried out using quantitative and qualitative research methods. For the quantitative part, a sample size of at least thirty was found to be acceptable (see Sekaran, 2003, p. 295; Erdos, 1983; Oppenheim, 1992; and Roscoe, 1975). Forty-three respondents were used for the qualitative inquiry part for this research project. In qualitative inquiry, no general rules have been set with regard to sample size, but depends on what is deemed to be required from case to case depending on method of inquiry (see Patton, 2002 p. 244; Stake, 1995; Yin, 2003; and Adelman et al., 1980). Quota sampling was used for the survey and snowball sampling, also known as chain referral sampling, was used for the video observation. Quota sampling was chosen because it is more specific when dealing with the sizes and proportions of sub-samples, as in the sub-groups here that helped reflect corresponding proportions in the population (Sekaran, 2003). Using quota sampling also helped the researcher identify participants based on selected criteria. Snowball sampling, which is considered a type of purposive sampling (Patton, 2002), was used to find and recruit “hidden populations” that are not easily accessible to researchers through other sampling strategies. This method allowed an approximate constructing of the “social network” by building up a social structure from a set of individuals and organizations connected to the hidden population. Moreover, this method of sampling was done because of a difficulty for the researcher to get an access in automotive industries since all car companies involved in this research classify their styling department as a prohibited area to other people.

The schematic representation of this research (see Figure 10) illustrates how the theoretical studies, empirical studies and publications fit into an overall structure where the parts complement each other.

#### *Theoretical studies*



The theoretical research activities constitute fulfillment of the formal coursework requirements related to my PhD studies, in the shape of four courses taken at NTNU, TU Denmark, and TAIK/Aalto University. With respect to my main doctoral project on “Practice-based design thinking for form development and detailing,” I studied how designers developed meaningful forms or form progressions, which differs from automated morphing. In order to shed light on this topic, surveys were conducted involving focus groups and individual respondent from design departments in the automotive industry (Proton, Perodua, NAZA, Modenas, Proreka, and Inocean AS), as well as renowned automotive design universities. In terms of finding the test subjects, I carefully selected the focus groups and respondents from the automotive design industry in conjunction with the respective managers, whereas lecturers in charge of design projects at the participating universities (Coventry University, the Royal College of Art in London, NTNU, Umeå University, and UiTM) introduced the test subjects to me.

Pilot studies were completed by the middle of 2007, whereas full-fledged empirical data collection and triangulation exercises were undertaken in 2008 and 2009.

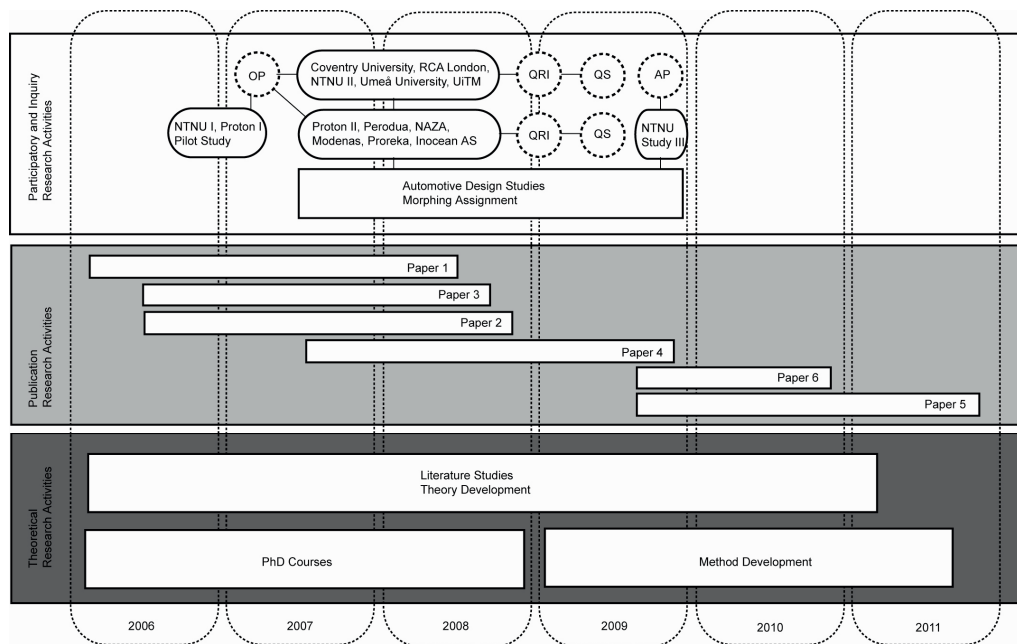


Figure 10. Schematic representation of research activities carried out during the research work consisting of theoretical studies, empirical studies and publications. Explanation of the abbreviations: OP = Observing participation, AP = Active participation, QRI = Qualitative research interview, and QS = Questionnaire study.

**Empirical studies and publications**

Research and publication activities resulted in three papers in 2008 (see Papers 1, 2, 3), one paper in 2009 (see Paper 4), one paper in 2010 (see paper 6) and one paper in 2011 (see Paper 5). Paper 1 described the foundation of the study based on the approaches of the “old masters” of engineering design, and the modern form development of automobiles. Paper 2 described the role of *formgiving* in design,

which can be interpreted as the part of form creation during which the aesthetic elements are introduced. In Papers 1 and 2, I used content analysis in order to establish a foundation for the quantitative as well as qualitative automotive elements, features and characteristics to be further elaborated upon on in Papers 5 and 6. Paper 3 explored the ways in which form is embodied through design activity. The use of verbal protocol analysis in Paper 3 revealed some interesting findings. A questionnaire was formulated for the study of car silhouettes in relation to human expression (see Paper 4). In order to investigate what expressions portray, questions were asked with respect how respondents: (1) Recognize the common characteristic of the car, (2) Indicate the words corresponding to the expression, and (3) Interpret the car images in comparison to human expressions. A total of 46 respondents answered the questionnaire. For papers 5 and 6, I conducted comprehensive experiments where video observations complemented with reflection techniques were carried out on 43 practicing designers and students.

The focus was on how designers understood and transformed elements, features and components based on selection and on notions of consistency and completeness in manual morphing operations. Video observations focused on how these participants developed and detailed overall and selected automotive forms through morphing sequence exercises. This led to a total of 645 observed sketches. (*43 participants x 3 sketches (Morphing at ratios of 25%, 50%, and 75% for each single view of the car) x 5 views of the car (i.e., Front view, Side view, Rear view, Three quarter front view, and Three quarter rear view)*). The template for video observation and verbal protocol analysis was based on the Delft Protocol method (see Cross, Christiaans, & Dorst, 1996).

Complementary to the above, controlled experiments consisting of video observation and semi-structured interviews were carried out with 10 master's degree students of product design at NTNU. Their task was to analyze selected sketches produced by the 43 practicing designers involved in the experiment. Selected sketches were then used as a basis for semi-structured interviews where 10 NTNU MSc students heuristically indicated their opinions on the overall form, features and components of the car with respect to whether these elements deviate from an expected natural progression of form development. The semi-structured interviews were complemented with video observations.

## 4. Results

This chapter presents six major contributions to a new body of knowledge within the context of this research. These contributions are as follows: (1) Terms for a qualitative structure in automotive design relating to approaches involving aesthetic features are established; (2) A format for analyzing linguistic interpretations of aesthetic elements is developed; (3) It is demonstrated that the metaphorical form in relation to sign and symbol is embodied in text, drawings and human tactile behavior (such as touching); (4) Two types of positive correlations are identified. These correlations are:

- The designer's perceptions of form elements, form features, and components related to common characteristics of a car, and
- Words related to car expressions and human expressions of the car;

(5) A method for analyzing manual interpolative morphing complementary to automated CAD morphing is developed. This method will support designers in their choices and transformations of form based on subjective and purposeful intent; and (6) A method for analyzing designers' perceptions with respect to perceptual characteristics, such as recognition, comprehension and association, is also developed.

### 4.1 Terminology of Qualitative Structure in Automotive Design

In this research, the term of "qualitative structure" within the context of automotive design was established and substantiated through the analysis of aesthetic features in form creation, in which the qualitative element was emphasized. The measurements were based on the quality of visual appearances in the form development process of automobiles. These aesthetic features are attached with a visual appeal based on human sensations of product form in relation to syntactic, pragmatic and semantic interpretations. Even though the terminology is subjective, it can still be measured by using a semantic difference scale and sketch analysis to test the use of language, such as what the adjectives can tell us about meaning. Currently, the term of qualitative structure is not part of the commonly used terminology within the field of car design. Therefore, in professional industrial and engineering design language, quantitative structure and quantified structure may in certain cases refer to the same type of structured design approach. This approach is based upon the use of principle solutions in problem solving. Detailed explanations about this new term can be found in Papers 1 and 2 of this study.

### 4.2 Linguistic Interpretations of the Aesthetic Element

It is common practice to use language or linguistics in the interpretation of form in the *formgiving* process of automotive design. *Formgiving* is a commonly used term in Scandinavian countries to represent the form creation activity. The meaning of form based on aesthetic elements can be described by means of semantic and semiotic interpretation. On one hand, it can be explained through design-inspired and measurement approaches based upon an understanding of engineering principle solutions; on the other, design of form can be based on patterns in nature and

mechanical functions as well as other factors such as the code of language, semantics, symbols, reproductions, or the individual choices of designer. In design related to art and design there is a preference for using qualitative measurement to document findings.

In this research, I have described form in relation to aesthetic elements. Aesthetics is a sub-field of *formgiving*, which emphasizes natural (e.g., beautiful or ugly) as well as spatial conditions. Aesthetics is also the study of the effect of product gestalt based on human sensations. In order to be a function of linguistic interpretation, aesthetics must be measured according to a scale using a high degree of order with low complexity (Warell, 2001), such as semantics and semiotics. Understanding the linguistic interpretation of aesthetic elements can also be a valuable asset for teaching *formgiving* in design education. Existing form transformation approaches using morphing related to zoomorphism have already been introduced in design education, in the shape of selected design exercises. In these exercises, students are for example asked to identify and relate animal features to an object which originally has no human characteristics, but which has the potential to adopt such characteristics and become more humanized. An example of such an object is a car. Detailed descriptions of this study are given in Paper 2.

### **4.3 Form Embodied in Text, Drawing and Tactile Aspects**







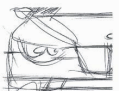

Western philosophers like Lakoff and Johnson (1999) have described metaphorical form as embodied. In order to test that statement, an empirical study was conducted using verbal protocol analysis. The observations of sketching practices revealed that, when the designer talked aloud, the element of uncertainty which is embedded in verbal expression and text was made explicit through the designer's interaction with for example a poster (mood board) (see Paper 3). A closer look at the drawings revealed that the designer replicated certain characteristics and specific elements of existing objects into their sketches. At the semi-concrete level, the designer used his empty hand, for example by gripping his fingers, in order to feel the visual object and reflect its form in relation to tactility. These findings indicate that the metaphorical form is indeed embodied. The detailed explanations of this study are available in Paper 3.

### **4.4 Positive Correlations of Designers' Perceptions**

In terms of studying the relationship between car silhouettes and human expressions, questions were framed in relation to the following: (1) Common characteristics of cars, (2) Words related to car expressions, and (3) Human expressions of the car. Table 1 illustrates positive correlations of designers' perceptions. The frequency distribution of importance rating of form elements indicates that "line" and "volume" are extremely important. The percentages for the designers' ratings of the principle of form indicate that "scale and proportion" as well as "balance" are extremely important. The percentages for selected form features as rated by designers indicate that "accelerate features (curves, line, surface)" and "radius" are extremely important. The percentage score of designers who strongly agree with a set of bi-polar adjectives indicates that "aggressive-submissive," "dynamic-static," "elegant-not elegant," "exclusive-not exclusive," "futuristic-nostalgic," "streamlined-rugged," and "soft-hard" are among the popular

features to take into account. Results from the study indicate positive correlations in designers' perceptions for all of these variables. This includes correlations with regard to significant components (e.g., head lamp, radiator grill and tail lamp); correlations between the form element and the expressions of the car's front view, side view and rear view (e.g., line, and the association of Chevrolet Camaro with the words of aggressive, confidence, cheerful and futuristic, etc); correlations between form features and bi-polar adjectives (e.g., Cut-line and Anger-calm, etc); and correlations between car components and form features (e.g., head lamp and radius, etc). It became noticeable in this research, that there are two styles of structured questionnaires where word pairs of bi-polar adjectives are employed on a semantic differential scale. The first style is a direct contradiction of word pairs. In the direct contradiction style the word selected explicitly represents the meaning, as in "beautiful" versus "ugly". The second style is an indirect contradiction of word pairs. In the style of indirect contradiction the selected word implicitly represents the meaning, such as in "beautiful" versus "not beautiful". The detailed explanations about this are available in Paper 4. In addition, Errata in Tables 2.1 and 2.2 describe the details of a Chi-square test which indicates that respondent perception in this survey is dependent on the image of the car model.

Table 1. Positive correlations of designers' perceptions

Test	Item	Scale	Percentages and significant values	Example
Frequency distributions	Form elements	Extremely important	Line (54.3%); Volume (52.2%)	 Line of car
	Principle of form	Extremely important	Scale and proportion (73.9%); Balance (41.3%)	 Scale and proportion of car
	Form features	Extremely important	Accelerate features (curves, line, surface) (34.8%); Radius (32.6%)	 Accelerate line features at bonnet and head lamp
	Bi-polar adjectives	Strongly agree	Aggressive-submissive (52.2%); Dynamic-static (56.5%); Elegant-not elegant (45.7%); Exclusive-not exclusive (45.7%); Futuristic-nostalgic (47.8%); Streamlined-rugged (50%); Soft-hard (41.3%)	-
Pearson Correlation Sig. (2-tailed)	Components	Positive correlation	Head lamp-Tail lamp (.356*); Radiator grill-Tail lamp (.708**)	 Head lamp  Tail lamp
	Form elements and expressions of car	Positive correlation	<u>Front view:</u> Line and Chevrolet Camaro with the words of aggressive, confidence, cheerful and futuristic (.524**); Surface and Chevrolet Camaro with the words of aggressive, confidence, cheerful and futuristic (.312*); Line and Aston Martin DB9 with the words of aggressive, confidence, elegant and speed (.361*); Line and Ford Cougar with the words of aggressive, dynamic, happy, odd and ordinary (.405*); Point and Mitsubishi Lancer with the words of aggressive, anger, confidence and brave (.435**) <u>Side view:</u> Line and Lotus Elise with the words of dynamic, sporty, fast and streamlined (.460**); Line and Jaguar XK Coupe with the words of sleek, aerodynamic, classy, contemporary and streamlined (.405**); Line and Toyota Yaris with the words of cute, cheeky, compact, contemporary and smart (.398*); Jaguar S-type with the words of elegant, exclusive, formal and traditional (.450**) <u>Rear view:</u> Line and Lotus Elise with the words of dynamic, sporty, fast and streamlined (.327*)	 Line of Chevrolet Camaro gives an expression of being aggressive, confidence and futuristic
	Form features and bi-polar adjectives	Positive correlation	Cut-line (.323*) with Anger-calm; Coning (.327*), Radius (.296*) with Charming-displeasing; Bulge (.339*) with Cheeky-backward; Arch (.309*), Hollow (.347*) with Cheerful-sad; Arch (.424**), Extrusion (.362*), Hollow (.393**), Lathe (.314*), Pooches (.328*) with Comfortable-uncomfortable; Concave (.309*) with Consistence-inconsistence; Concave (.330*) with contemporary-traditional; Blister (.386*), Concave (.333*), Dimple (.455**), Hollow (.397**) with contempt-not contempt; Coke bottle/Wasp-waist (.342*) with Disgust-not disgust; Arch (.359*) with Excited-bored; Bulge (.300*), Extrusion (.293*), Hollow (.419**), Lathe (.312*), Sheer (.390**) with Fear-brave	 Cut-line (a division between two panels of head lamp and bonnet) has positive correlation with bi-polar adjective of Anger-calm
	Components and form features	Positive correlation	Head lamp and radius (.333*); Rear bumper and blister (.334*)	 Head lamp component and radius form features at car body

\* Correlation is significant at the 0.05 level (2-tailed)  
\*\* Correlation is significant at the 0.01 level (2-tailed)

## **4.5 Manual Interpolative Exercises Complementary to Automated CAD Morphing**

With regard to the practical application of Automated Morphing Systems (AMS) within the context of CAD, it has been observed that AMS is unable to establish meaningful form development progressions which can replace a designer's reflective conversation with the situation, form and materials. Results from this study show that designers choose and transform form based on subjective and purposeful intent, whereas CAD-based morphing through automated morphing systems lacks this basis. Therefore, up till now, AMS has been more widely applied in the exploration of form variations at a more concrete and routine level based upon a clearly defined objective (convergent transformation). This routine-based transformation process using AMS typically occurs during the later stages of the styling process. However, results from the current study have opened avenues for improving AMS used at an earlier stage of the form development process. Findings indicate that in fact, rather than transform uniformly, designers choose what elements to morph. This implies that they are more comfortable working at a level of more concrete detail initially, before moving on to a more advanced level of form development. Here, the types of elements selected by designers seem to be characterized by having functional purpose. In contrast, the typical behavior of AMS would have yielded the same number of transformations regardless of the form structure level. As a consequence, the inability of AMS to recognize purpose means that these systems are extremely useful for supporting advanced level form generation. Hence we propose that the most beneficial application of automated morphing is at the superior level of form generation.

On a more general note, early stage development processes are shown to be categorized by divergent and explorative processes. By understanding how designers generate form variation at the superior, intermediate and lower form levels, improvements could be suggested which would enhance the ability of AMS to morph selectively and inconsistently, thus introducing ambiguity and variance. These improvements would rely on enabling the AMS to recognize the type and purpose of form elements, possibly through the use of approaches such as genetic algorithm or fuzzy logic. Furthermore, systems with such characteristics are already emerging in the field of form optimization. These may provide a suitable development possibility for AMS in the future. The details about these findings are described in Paper 5.

## **4.6 Representational Content in relation to Form Structure and Form Meaning based on the PPE framework**

When selected design sketches were used in a controlled experiment involving video observation and semi-structured interviews, it transpired that the 10 evaluating MSc students from NTNU perceived things differently compared to the results from the morphing exercise with the 43 designers – represented in the form of ideas and visual hand sketches. However, even though the designers' perceptions varied due to the representation format of the ideas (visual sketches made by hand), meaning can still be deduced from the results. Some of it can be categorized with respect to designers' perceptual characteristics according to the Perceptual Product Experience (PPE) framework, including qualities such as

recognition, comprehension and associations. This shows that the PPE framework can be used as a useful tool for establishing familiarity, understanding quality characteristics and the nature of the product's form structure, determining meaning, and assessing the values of form elements. The details about these matters are described in Paper 6.

Based on the six results described above, the following summary highlights the major conceptual and empirical contributions of this thesis.

#### ***Conceptual contributions***

1. *Cross-disciplinary and multi-disciplinary approach:* Samples in Papers 4, 5, 6 are based on respondents using different approaches and disciplines such as automotive design, industrial design and product design.
2. *Understanding form and reliability:* Findings in Papers 1, 2, 3, 4, 5 and 6 made in the exploration of form in relation to different approaches and strategies of quantitative and qualitative structure.
3. *Qualitative data on sketching activities:* Findings in Paper 3 using protocol analysis to study metaphorical form, such as sign and symbol, in relation to design activities and findings in Papers 5 and 6 using natural video observations.

#### ***Empirical contributions***

1. *Visual information on form in design:* Findings in Papers 1, 2, 3, 4, 5 and 6 exploring visual information on a scale ranging from abstract to concrete.
2. *Functional reliability:* Findings in Papers 5 and 6 indicate that visual data can make the functional reliability explicit.
3. *Adopting manual morphing into the CAD and AMS systems:* Findings in Papers 5 and 6 exploring manual interpolative morphing through freehand sketching demonstrate that it can assist in improving the application of CAD and AMS.
4. *Exploring the PPE framework in relation to form studies:* Findings in Paper 6 exploring a potential area of improving CAD and AMS in relation to form semantics and syntactics.



## 5. Summary of Papers

### 5.1 Paper 1 - The "Old Masters" of Engineering Design and the Modern Form Development Process of Automobiles

<b>Authors:</b>	Shahriman Zainal Abidin, Jóhannes Sigurjónsson and André Liem.
<b>Authors' contributions:</b>	Abidin led the writing process. Sigurjónsson and Liem participated through consultations on the structure and content-based analysis; they also contributed in the writing process.
<b>Published in:</b>	<i>Proceedings of the Design 2008, at 10<sup>th</sup> International Design Conference, Dubrovnik-Cavtat, DS48-2, 1199–1206.</i>
<b>What was already known on the topic:</b>	Most of the existing methods for the modern form development process of automobile exterior design are structured around “concretization” of the product during the design process. Therefore, the “Old Masters” way of working has been adapted to the different degrees of concretization of the product. This technique emphasizes the use of quantitative structures, such as principle solutions. However, not much research has been conducted on <i>designer-centered</i> approaches. <i>Designer-centered</i> means to focus on the cultural, aesthetic, and emotional values of design with regard to tacit frames of an individual in relation to his/her practice, cultural circumstances, methodology, etc.
<b>What this study adds to our knowledge:</b>	<p>In this study, we attempted to identify areas related to <i>formgiving</i> and design, where Computer Aided Design (CAD) systems, especially within the context of automated morphing, have been unable to contribute in terms of aesthetics. With the objective of developing a better design process, we compared the “Old Masters” of engineering design and the modern form development of automobiles. This comparison study revealed the need for a detailed, descriptive study of form development at work.</p> <p>In this context, this paper discussed some important aspects for form development from the “Old Masters.” Specific case examples were based on the development of “Excavators” by Tjalve (1976) and a series of forms from morphing a “New Beetle to a BMW” by Chen et al. (2003).</p>
<b>Relation to research questions:</b>	<ul style="list-style-type: none"><li>• How do car designers generate exterior form through the interactions among their sketching activities and implicit/cognitive thinking patterns supported by their attitudes, values, beliefs, and contextual assumptions?</li><li>• What were the differences in form development between Automatic Computer Aided Morphing and manual form generation conducted by designers?</li></ul>

## 5.2 Paper 2 - On the Role of *Formgiving* in Design

<b>Authors:</b>	Shahriman Zainal Abidin, Jóhannes Sigurjónsson, Martina Maria Keitsch, and André Liem.
<b>Authors' contributions:</b>	Abidin led the writing process. Sigurjónsson, Keitsch, and Liem participated through consultations on the structure and the content-based analysis. Sigurjónsson, Keitsch, and Liem also contributed in the writing process.
<b>Published in:</b>	<i>Proceedings of E&amp;PDE 08, 10<sup>th</sup> International Conference on Engineering and Product Design Education - New Perspective in Design Education, Barcelona, DS46-1, 365–370.</i>
<b>What was already known on the topic:</b>	For more than 20 years, the word <i>formgiving</i> or <i>form-giving</i> has been commonly used in Scandinavian countries. According to the Norwegian dictionary, the meaning of “ <i>formgiving</i> ” or “ <i>formgjeving</i> ” is fashioning, molding i.e., industrial design. Previously, most of the design authors in the world used the word “shaping” in the same meaning as <i>formgiving</i> . Moreover, available Standard English dictionaries do not interpret the meaning of <i>formgiving</i> . It seems that the use of the word <i>formgiving</i> has become popular among many design authors when discussing design practice. <i>Formgiving</i> , when used in engineering design, relates sometimes to a specific phase in the design process: the part in which a principle solution is developed into a materialized design. The emphasis is on the embodiment, the determination of form and material, and the process of bringing both the embodiment and the determination of form and material in line with one other.
<b>What this study adds to our knowledge:</b>	For industrial design, the interpretation of word was identified as being toward a direction of artistic visual elements in relation to the discipline of art and design. Meanwhile, for engineering design, the interpretation of word was identified as toward a direction of engineering-principle solutions in relation to the discipline of technology and engineering. In the understanding of the approaches of <i>formgiving</i> in industrial design, qualitative elements in relation to quality of form have been emphasized by the designer in appreciation of design. Meanwhile, in engineering design, quantitative elements in relation to quantity or amount of form are common. In the assessment of form in relation to design, the totality of <i>formgiving</i> can be examined by using linguistic interpretations. <i>Formgiving</i> can also be influenced by aesthetic features. The concept of aesthetics in this perspective can be interpreted as a study of the effect of <i>formgiving</i> on human sensations. The focus in this study was on the appearance or the consequence of the form. This differed from most/previous publications which dealt with creation and appreciation of the form.
<b>Relation to research questions:</b>	<ul style="list-style-type: none"><li>• How do car designers generate exterior form through the interactions among their sketching activities and implicit/cognitive thinking patterns supported by their attitudes, values, beliefs, and contextual assumptions?</li></ul>

- What were the differences in form development between Automatic Computer Aided Morphing and manual form generation conducted by designers?

### 5.3 Paper 3 - The Embodied Mind in Relation to Thinking about Form Development

<b>Authors:</b>	Shahriman Zainal Abidin, Hans Vanhauwaert Bjelland, and Trond Are Øritsland.
<b>Authors' contributions:</b>	Abidin led the writing process. Bjelland and Øritsland participated through consultations on the structure and the verbal protocol analysis; they also contributed in the writing process.
<b>Published in:</b>	<i>Proceedings of NordDesign 2008 Conference, Tallin, DS50, 265–274.</i>
<b>What was already known on the topic:</b>	There are several directions of theoretical and neurological explanations for creativity and intuition. Creativity and intuition come from the basic motor properties in the brain. We know that technical function might be understood by the actions of the body. The designer can also work backwards: starting with the functions the product is supplying to the user and using these to create representations of internal technical processes. The common term used in the technical development process related to the creation of new design is <i>formgiving</i> . For <i>formgiving</i> in relation to the automobile industry, concepts such as “bone line” and “body” are used when describing a car as a form.
<b>What this study adds to our knowledge:</b>	The study explored whether designers use some kind of metaphorical understanding instead of structural principles. A verbal protocol analysis showed that, in order to understand product form while drawing it, designers react in several ways, including through form language, visual expressions, and use of an empty hand. This led us to think about how mental images interact in some way with action schemes to play a part in the designers' apparently intuitive ways of “ <i>formgiving</i> ”. This is in line with Lakoff and Johnson's proposal that metaphorical thinking is embodied. The results suggested that a closer look at embodied mind theory might benefit the understanding of some of the apparently intuitive processes of the designer. Such a study may provide us with ways of understanding and facilitating intuitive processes in design.
<b>Relation to research questions:</b>	<ul style="list-style-type: none"> <li>• What were the differences in form development between Automatic Computer Aided Morphing and manual form generation conducted by designers?</li> </ul>

### 5.4 Paper 4 - Designers' Perceptions of Typical Characteristics of Form Treatment in Automobile Styling

<b>Authors:</b>	André Liem, Shahrman Zainal Abidin, and Anders Warell.
<b>Authors' contributions:</b>	Liem led the writing process. Abidin conducted research fieldwork. Warell participated through consultations on both the structure of the study and the analysis of the data based on questionnaire surveys. Warell also contributed to the writing process.
<b>Published in:</b>	<i>Proceedings of Design and Semantics of Form and Movement, 5<sup>th</sup> International Workshop on Design &amp; Semantics of Form &amp; Movement (DeSForM 2009), Taipei</i> , 144–155.
<b>What was already known on the topic:</b>	Automotive designers are challenged by differentiating car models based on a common platform at the corporate-brand or product-brand level. In relation to these brand levels, the explicit visual references are embedded in the design features designers implement with the intention that the design be immediately perceived and recognized. Such characteristic elements may have syntactic or semantic roles in product design. Previously, qualitative methods have been developed by design researchers in order to identify and assess such characteristic elements. Later, the intuitive feelings were formalized and structured via Kansei Engineering; consumer feelings and demands were used to design a new product.
<b>What this study adds to our knowledge:</b>	<p>In this study, we discussed three perspectives on how designers perceive characteristics of form treatment in automobile styling. First, general perceptions of car designers, which are most relevant for automobile styling were identified. Second, an understanding was developed on how these perceptions, expressed as adjectives, can be used as a basis for selecting a range of factors and characteristics typical for car design. These expressed adjectives represent form features, form elements, and form principles. Third, selected bipolar adjectives as spectra for morphing were explored.</p> <p>The study showed that there are valid correlations between selected designers' perceptions and form elements/car components of an automobile. Hypothesis testing using the chi-square test showed that the designer's perception is dependent on the respective car model image (see Errata Tables 2.1 and 2.2). This justifies the search for how these selected designers' perceptions can be used as a foundation for automobile styling.</p>
<b>Relation to research questions:</b>	<ul style="list-style-type: none"> <li>• How do car designers generate exterior form through the interactions among their sketching activities and implicit/cognitive thinking patterns supported by their attitudes, values, beliefs, and contextual assumptions?</li> <li>• How were exterior car designs influenced by preceding designs, and which specific elements, features, etc. were addressed in the generation of incremental or radical design changes with respect to these preceding designs?</li> <li>• What were the differences in form development between Automatic Computer Aided Morphing and manual form generation conducted by designers?</li> </ul>

## 5.5 Paper 5 - Understanding Styling Activity of Automotive Designers: A Study of Manual Interpolative Morphing through Freehand Sketching

<b>Authors:</b>	Shahriman Zainal Abidin, Anders Warell, and André Liem.
<b>Authors' contributions:</b>	Abidin led the writing process. Warell and Liem participated through consultations on both the structure of the study and the analysis of the data based on video observations and semi-structured interview. Warell and Liem also contributed to the final stages of the writing process.
<b>Published in:</b>	<i>Proceedings of ICED 11, 18<sup>th</sup> International Conference on Engineering Design, Copenhagen, DS68-9, 357–366.</i>
<b>What was already known on the topic:</b>	Designers widely employ manual sketching as a tool to explore and understand new ideas and concepts for form and function in product design. The actual process of creating design ideas is usually envisaged as an ongoing process in the designer's mind where drawings are seen as media to reproduce the designer's mental images. Thus, the design activity regards designing as a conversation with its materials in specific situations conducted in the medium of drawing and crucially dependent upon seeing. In other words, its reflective conversation with materials based on a structure of seeing-moving-seeing is an interaction of designing and discovery. A divergent approach, searching for more types of solutions, is generally employed early in design processes, while a narrower but deeper exploration of variance is used once a theme has been selected. The inherent characteristics of designers' processes of thinking and sketching – being vague, fluid, ambiguous, and amorphous – render them beyond the capacity of current computational systems.
<b>What this study adds to our knowledge:</b>	We observed sketching activities of automotive designers in order to understand their processes of manual interpolative morphing employing freehand sketching. Results suggested that there are profound differences between manual and automated morphing. Specifically, these differences relate to selectivity, consistency, and completeness of morphing operations. While designers choose and transform shape based on subjective and purposeful intent, Automated Morphing Systems (AMS) lacks these characteristics. These differences influence the outcome of morphing processes to a fundamental degree. Designers and design teams will be supported by these findings when considering the implementation of AMS in design work. The research described the characteristics and clarified the potential contribution of AMS in styling activities, thus assisting the evaluation of AMS in relation to traditional, manual sketching approaches.
<b>Relation to research questions:</b>	<ul style="list-style-type: none"><li>• How do car designers generate exterior form through the interactions among their sketching activities and implicit/cognitive thinking patterns supported by their attitudes, values, beliefs, and contextual assumptions?</li></ul>

- How were exterior car designs influenced by preceding designs, and which specific elements, features, etc. were addressed in the generation of incremental or radical design changes with respect to these preceding designs?
- What were the differences in form development between Automatic Computer Aided Morphing and manual form generation conducted by designers?

## 5.6 Paper 6 - The Significance of Form Elements: A Study of Representational Content in Design Sketches

<b>Authors:</b>	Shahriman Zainal Abidin, Anders Warell, and André Liem.
<b>Authors' contributions:</b>	Abidin led the writing process. Warell and Liem participated through consultations on both the structure of the study and the analysis of the data based on video observations and semi-structured interview. Warell and Liem also contributed in the final stages of the writing process.
<b>Published in:</b>	<i>International Journal of Design and Innovation Research</i> , 5(3), 47-60, 2010, ARTS-IJODIR.
<b>What was already known on the topic:</b>	As competition intensifies, design offers a potent way to position and differentiate products in the minds of users. However, this requires users to understand radically new languages and messages, to find new connections to their socio-cultural context, and to explore new symbolic values and patterns of interaction with the product. Such new user value includes utility and social significance as well as emotional and spiritual value. Social significance value is embodied by representational characteristics of product form, such as semantic and identity aspects. However, there have been few initiatives to consciously introduce representational issues in design and brand development. In order to gain greater awareness of the link between designing and branding, it may be useful to connect product design features to representation. The knowledge of how to do this has not yet been thoroughly established.
<b>What this study adds to our knowledge:</b>	In this work, the framework of product experience was utilized in order to better understand the significance of form elements and how these form elements can enhance the development of brand attributes. Designers were asked to provide their interpretive, expressive characteristics of car images and to make sketches through manual morphing exercises. This was followed by master's degree students interpreting the sketches of designers' morphing sequences. In the experimental investigation of the sketching process through morphing sequence exercises, designers used individually driven styles and approaches when creating product form. These approaches produced characteristically different form ideas; these differed and yet also showed consistency with respect to car category, expression, identity, recognition, format, composition,

complexity, etc.

Typically, assessment of generated sketch work and ideas is conducted using relative heuristic evaluation in a comparative design review. Given a large set of automotive sketches, general patterns of styling emphasis can be identified. The paper concluded that perceptions of designers are varied due to the representation format of the ideas as visual hand sketches. Visual hand sketches point out certain meaning and may be categorized with respect to perceptual characteristics according to the PPE framework. The visual hand sketches suggest that a tool to support evaluation and generation of early design concepts can be developed. This may support the generation of form ideas with desired characteristics for a brand, product category, and market.

**Relation to  
research  
questions:**

- How do car designers generate exterior form through the interactions among their sketching activities and implicit/cognitive thinking patterns supported by their attitudes, values, beliefs, and contextual assumptions?
- How were exterior car designs influenced by preceding designs, and which specific elements, features, etc. were addressed in the generation of incremental or radical design changes with respect to these preceding designs?
- What were the differences in form development between Automatic Computer Aided Morphing and manual form generation conducted by designers?
- What are the meanings of elements and features that were manually and unexpectedly transformed by designers, and how do these relate to preceding designs?

## 6. Discussion

The concluding chapter of this thesis will discuss what has been learned as well as the value of this research. This research focuses on practice-based design thinking for form development and detailing, specifically with respect to automotive design. In this discussion, a specific standpoint is taken toward the educational and professional perspectives of *formgiving* in automotive design, as these have been natural starting points for this research. Human thought processes are unpredictable and inconsistent and can lead to surprising and creative results. However, there is a gap between how the human mind actually works and how one operates CAD and AMS applications. Empirical studies on manual morphing should suggest improvements for CAD and AMS applications that will reduce this gap and also enable CAD and AMS to take a more facilitative role in the development of “creative” results. This may benefit designers, both in academia and in professional practice, particularly with regard to thinking about form.

### 6.1 Formgiving in relation to Future Automotive Design Education and Practice

The understanding of *formgiving* in automotive design education and professional practice is essential for design students and practicing designers. Automotive design is a sub-area of study under the frame of industrial design (see Tovey, 1992). In engineering design, industrial design has been recognized as a specialized area that contributes to the development of new products (see Pahl & Beitz, 1996).

In the development process of automotive designs, it is possible to use quantitative and structured approaches from engineering design to determine frameworks and structures for *formgiving*. However, a qualitative approach to *formgiving* supported by reflective and hermeneutic practices is more commonly adopted in automotive design. Automotive design is much more related to the art-based school of thought in design thinking and designing, where the context is not only the creation of useful artifacts or forms but also the creation of beauty in relation to form (see Louridas, 1999).

Thus, in design science, utility and aesthetics are intertwined. The *work of art* is a representation of something in the representation of art. This is a part of the visible world. In *non-representation* of art, the work of art might represent something else in its thoughts and ideas. Meanwhile, design science is related to science appreciation. It is concerned with discovering facts about the world as well as challenging the world (see Louridas, 1999). The work of science is related to reasoning as well as the concreteness level of the forms.

In this research, we can see how, in creating form, the elements of art and science blend together in order to meet current design challenges in the form development process of automobiles. The use of problem-solving and synthesis-analysis strategies in the designing process allows the incorporation of elements of experience and intuition from the automotive designer. These problem-solving and synthesis-analysis strategies as well as elements of experience and intuition can be quantitatively and qualitatively structured. In this research, the patterns of *formgiving* and concepts such as “bone line” and “body” used in describing an automotive external design (e.g., syntactic, pragmatic, and semantic) have been identified and can be explicitly described and formalized. These formalizations



represent designers' behavior and design attitudes. In the future, the formalizations may be developed into design tools that can be formally taught within specific contexts. For example, in the analysis of form structure (syntactic) in this research, I found that designers focused consistently on the specific region of the car at the intermediate form level (form features) and the detail form level (components) rather than the superior form level (Gestalt). This finding might be the basis of formalization. To address and minimize the diversity of designers' individual styles and approaches, a normative design reasoning approach can be used to interpret certain forms with respect to sub-modes of representation in accordance within the PPE framework. Results also indicated that, at a preliminary presentation level (e.g., sketch level), meaning can be analysed and categorised into perceptual characteristics according to the PPE framework. From an educational perspective, this PPE framework can be taught as a tool to evaluate and generate early design concepts to support the generation of form ideas with desired characteristics for a particular brand, product category, and market. In short, the use of the PPE framework in design education and practices can make form interpretation more structured in documenting findings and establishing facts.

In terms of teaching basic design, certain results from this study can be used to further develop fundamental *formgiving* strategies. These fundamental strategies concern the semantic (meaning), pragmatic (facts) and syntactic (structure) concepts in automotive design education and practice.

## **6.2 Design Thinking and Reasoning within the Context of Automotive Design Education and Practice**

Recently, design thinking with respect to design education has become an increasingly important issue for academic research and design practice. Design thinking relies completely upon the designer's own memory, precedence, and language abilities (see Lawson, 2004). In this case, designers demonstrate their intuition, subjectivity, and tacit knowledge during the design process. How designers think is mostly unconscious, taking place through episodic memory, vague concepts, and imprecise definition (see Pahl & Beitz, 1996). In the design context, a solution-focused approach to problem-solving is used. Designers are forced to think of solutions to "ill-defined" problems that are not guaranteed and offer no constant conditions.

Research on design thinking related to *formgiving* is more cognitive in nature, addressing issues such as problem solving, procedural methods, heuristic reasoning, and the nature of the design problem. However, in order to improve design theory and process, it seems that the focus is traditionally has been more on understanding the correlations of design thinking with the phenomena of knowledge, application, and intention.

In this research, we can see that how the designer thinks about form can be categorized into quantitative and more prevalent qualitative approaches. The qualitative approaches are supported by my findings that suggest that designers' morphing and sketching processes are characterized by a low level of consistency (much variation between sets of transformations), a high level of selectivity (some elements are transformed while others are left unattended), and a low level of completeness (elements are only partially transformed throughout the stages of a morphing sequence). This is in accordance with Goel's (1995) description of the sketching process as being vague, fluid, ambiguous, and amorphous—characteristics

that are beyond the capacity of current computational systems. From a design reasoning perspective, the reflective practice and hermeneutic ways of thinking and design reasoning complemented this vagueness, fluidity, and ambiguity in the processes of car designing and sketching.

However, CAD and AMS morphing applications lack the hermeneutic and reflective reasoning capabilities needed during *formgiving* processes. Therefore, it is important to create awareness among practicing designers, design students, and design educators that the core differences between how designers design and how CAD systems morph can be deduced from a spectrum of design reasoning models, supported by certain worldviews. Contrary to how designers develop exterior automotive forms, CAD systems are built upon the roots of a positivistic and problem-solving model of design reasoning.

How the differences in designing between designers and CAD systems relate to different models of design reasoning is a theme for future research on *formgiving* in automotive design education and practice. Future research should focus on explaining the manifestation of design thinking to explore relationships between the methods of “research by-through design-designing.”

Research by-through design-designing is a part of data gathered on design through research projects. Data from research projects need to be compared with other data from interviews, user-testing, literature, expert reviews, etc. By doing this, one avoids having the research project be an entirely practice-based endeavor or a purely subjective, uncritical work (Rodríguez Ramírez, 2009).

### **6.3 Evaluation, Verification and Validation**

The means for verifying the validity of design theory are based on the principles of logical verification and verification by acceptance, as suggested by Buur (1990). Validation in this thesis is concerned with establishing the relevance and meaningfulness of guidelines, theories, methods, and tools. Validity is the degree to which a test measures what it is supposed to measure; it can include content area, constructions, concurrentness, and predictions (Yin, 2003; Buur, 1990).

In this thesis, evaluation of the work is seen as a continuous and ongoing process during the course of the research. The work is subject to scrutiny from outside sources (i.e., the scientific evaluation procedure) as well as from sources within the frame of the project (i.e., the researcher and the supervisors of this work). In addition, evaluations are continuously performed in personal design work, coursework, and industrial studies as well as through continuing discussions with automotive designers, colleagues, and university lecturers.

This research is dependent on the participation of selected designers representing different levels of career development, ranging from students to experts. It includes discussion sessions with experts in the area of automotive design representing academia and industry. The purpose of these discussions was to evaluate the internal consistency of respondents' answers and assess the findings of the studies.

#### ***Logical verification***

Logical verification means there is: (1) consistency between individual elements of the theory; (2) completeness (i.e., all relevant observed phenomena can be explained or rejected by the theory); (3) agreement between the theory and well-established methods; and (4) theoretical explanations for case studies and specific

design problems. In this research work, it is also necessary to show a clearly defined novelty in relation to well-established methods and theory. It has been applied at the analysis of syntactic, pragmatic and semantic for form development in automotive design.

#### ***Verification by acceptance***

Verification by acceptance requires that statements of the relevant theory (axioms, theorems) are acceptable to experienced designers as models and methods derived from the theory. Factors affecting acceptance include ease of understanding as well as complexity and the CAD and AMS interface.

This thesis includes verification of a correct understanding of the work context (see Papers 1 and 2) as well as verification of the contributed theoretical models, the information model, and the computer model.

For the statistical part of the study, the reliability of the analysis is based on the Cronbach Alpha (CA) model.

The CA model is based upon the internal consistency of the respondents' answers (see Sekaran, 2003, p. 327). It also analyzes the average correlation of items within a test when items are standardized (see Paper 4).

For the experimental part of the study (see Papers 3, 5, and 6), the reliability of the analysis is based on the direct evidence in the video observations (Patton, 2002).

## **6.4 Further Work**

This research has shown that, when designers think about form, the metaphorical form is embodied. Verbal protocol analysis was conducted on designers performing tasks of designing form; results indicated that form was embodied in several ways, including text, drawing, and human tactile behaviors. Results from surveys and observations showed positive correlations between designers' perceptions of form elements, form features, and components related to common characteristics of cars (e.g., words related to expressive aspects). Designers performed manual morphing exercises to stimulate them to think about *formgiving*; the information provided by these exercises can assist CAD- and AMS-morphing processes. Again, the use of the PPE framework in *formgiving* is significant for understanding form in relation to processes of design thinking. These findings may lead to improvements of *formgiving* processes, as they provide guidance to designers on how to both manually and digitally improve automobile-styling processes using design-thinking knowledge in design education and practice.

The insights gained through this work may be incorporated in future research via theoretical and empirical studies.

#### ***Theoretical study***

This study addresses form development through manual morphing approaches that may assist development of AMS environments. Complementary theoretical studies should address in greater depth how algorithms of existing and future CAD software systems may contribute to the development of new tools and software for form development and detailing in automotive design. The objective of a more thorough complementary study on algorithms is to create an appropriate test protocol based upon adapting a character of design, building, and testing form structure to a meta-model. The/this metal-model would separate/assign the morphs

into specific domains that support form meaning. Also, it is important to explore and develop algorithms for AMS which can control intuitive form features that may have arbitrary structure.

***Empirical analysis***

Other methods of research such as “simulation trials” in empirical analysis should be done in relation to a future study of CAD and AMS. These should be integrated into existing CAD programs and may lead to a new type of CAD software. This can be done through the improvement of CAD software via qualitative structure instruments or tools in the design process, and may contribute to a new body of knowledge through research in relation to cross-disciplinary and multi-disciplinary studies.

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## **8. Appended Papers**

## Errata

Paper 4, “Designers’ perceptions of typical characteristics of form treatment in automobile styling,” did not include a detail of the chi-square test on page 150. Please see Table 2.1 and Table 2.2 for this.

$H_0$ : Respondent perception is independent of car model image.

$H_1$ : Respondent perception is dependent of car model image.

Reject  $H_0$ . Conclusion: respondent perception is dependent of car model image.

Table 2.1. Observed and expected frequencies on the perception of the designer based on car-model image

	Model										Total
	Car 1	Car 16	Car 17	Car 19	Car 2	Car 3	Car 31	Car 33	Car 35		
No	Count	0	7	15	14	2	1	19	12	7	77
	Expected Count	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	8.6	77.0
Yes	Count	44	37	29	30	42	43	25	32	37	319
	Expected Count	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	35.4	319.0
Total	Count	44	44	44	44	44	44	44	44	44	396
	Expected Count	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	44.0	396.0

Note: Car 1 – Front view of Volkswagen New Beetle, Car 2 – Front view of Citroën DS, Car 3 – Front view of BMW 3 Series, Car 16 – Side view of Smart Fortwo, Car 17 – Side view of Mini Cooper S, Car 19 – Side view of Mitsubishi Galant Fortis, Car 31 – Rear view of Volvo S80, Car 33 – Rear view of Audi TT, Car 35 – Rear view of Volkswagen New Beetle.

Table 2.2. Chi-square tests

	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	53.718 <sup>a</sup>	8	.000
Likelihood Ratio	63.961	8	.000
N of Valid Cases	396		

a. 0 cells (.0%) have expected count less than 5. The minimum expected count is 8.56.



## **Paper 1**

The “old masters” of engineering design and the modern form development process of automobiles.

Abidin, S.Z., Sigurjónsson, J., & Liem, A. (2008). The “old masters” of engineering design and the modern form development process of automobiles. *Proceedings of the Design 2008, 10<sup>th</sup> International Design Conference, Dubrovnik-Cavtat, DS48-2*, 1199-1206.





## The “old masters” of engineering design and the modern form development process of automobiles

S. Z. Abidin, J. Sigurjónsson, and A. Liem

*Keywords: aesthetics, engineering design, form development*

### 1 Introduction

The modern form development process of automobiles exterior design (called hereafter the development process in short) traditionally consists of the embodiment design phase (or system-level design phase) followed by the detail design phase. However, few changes have been made concerning the design process itself. Most of the existing methods are often structured around “concretization” of the product during the design process: an iterative refinement and improvement of the features of the product until production launch. Thus, the “Old Masters” way of working has been adapted to the different degrees of concretization of the product.

The term “Old Masters” is used to describe approaches from Gerhard Pahl and Wolfgang Beitz (Pahl & Beitz), Vladimir Hubka (Hubka), Eskild Tjalve (Tjalve), and Karlheinz Roth (Roth) which have a common characteristic approach based on working with principle solutions. From our point of view, the development process can be refined with a *designer-centered* approach. *Designer-centered* means here to focus to a larger extent on values and the cultural, the aesthetical and the emotional aspect of the design. This is because in the design of manufactured products the specialist activities of industrial design (in this context automotive design) and a wide range of engineering design techniques are brought together [Tovey 1992]. So, *designer-centered* approach also means to regard the tacit frames of an individual [Schön 1991] in context with his/her practice, cultural circumstances, methodology, etc.

Comparing of the “Old Masters” of engineering design and the modern form development of automobiles may lead to a better design process, ensuring in turn more time and cost effective activities and hopefully a better product quality. We also see a need for a research approach, which in our work, consists of a descriptive study of the form development at work. In this context, this paper discusses some important elements for form development from the “Old Masters.” In the following, we will present the background of study, case examples based on the development of “Excavators” by Tjalve’s [1976] and series of forms by morphing a “New Beetle to a BMW” by Chen et al. [2003] and finally a conclusion.

### 2 Background

#### 2.1 The “Old Masters” of engineering design

Methods that describe the form development process are largely related to the product concretization process. Nevertheless, these methods often present elements that are oriented towards the designer’s knowledge and skills. An examination of these elements is the basis for this study.



One of the most detailed models of the form development process is described in Pahl & Beitz [1996]. They organize the embodiment design phase in 15 steps and the detail design phase in 5 steps. These steps logically encourage the practitioner to begin with the most important parts of the product (“the main function carriers”) and to iteratively refine and improve the layouts and form designs until the final design is produced. The detail design phase deals partly with the finalization of the product details and controlling of standards, and partly with the integration of all the documentation for production and archiving. In order to help the designer, a checklist is added to the process. The designer is encouraged to check systematically for a number of factors that have to be taken into consideration during the process. Accumulated experiences and practices have led to the application of some basic rules as *simplicity*, *clarity* and *safety*. Pahl & Beitz emphasize the use of these rules and the use of these experiences and design practices at any step of the embodiment design and detail design phases. Moreover, the design process is connected to a certain number of principles and guidelines that help the designer in dealing with specific aspects and related problems of the form design activity.

The theory of technical systems is central to Hubka’s work [see Hubka & Eder 1982]. The procedural model of the design process is structured around the concretization of the technical system. The steps are similar to Pahl & Beitz process, even if detail design phase by Hubka’s (e.g., establishment of tolerances and surface properties). The structural model of the design process [Hubka & Eder 1982] is the hierarchical decomposition of design activities. Below the level of the three main design phases (conceptual design, embodiment design, and detail design), the design activities are arranged in four levels, with respect to their complexity. Each activity of a lower level contributes to a higher – level activity. The first level, design operations, gathers all activities dedicated to the realization of the technical system, irrespective of the design phase. The second level contains the problem – solving process activities, and the third and fourth levels contain activities and actions that are independent of the design activity (e.g., “experiment” or “sketch”). The activities of each level are interdependent. Hubka has also dedicated a chapter to the designer describing what a designer *should* be, rather than describing the designer’s actions and their consequences for the design process [Hubka & Eder 1982]. In Tjalve’s [1976] *Systematic Designs of Industrial Products*, the phases of the form development process are denoted as system level design and detail design. The former focuses on the product architecture, while the latter focuses on actual details with regard to the embodiment and detailing of the product part. The system level design process guides a designer through the particular problem of product architecture.

Roth, in *Konstruieren mit Konstruktionskatalogen* [Roth 1989], regroups the form design phases into one single phase - detail design. Unlike the other approaches, the process is not divided between the conceptual design phase and the detail design phase. The designer may need to “jump” from one phase to another depending on his or her needs. Thus, a step is made towards the exploitation of the designer’s skills and knowledge. The designer’s degree of freedom is also emphasized. Instead of a process, two checklists are given, concerning general points and component design specification elements. As in Pahl & Beitz [1996] these are completed with a selection of principles and guidelines. The *simplicity* rule is also well-emphasized here as a designer role.

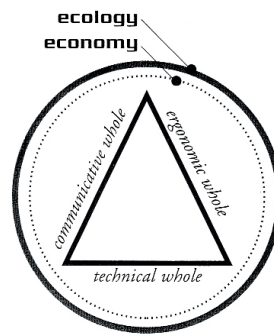
The strategies and the methods used by the “Old Masters” of engineering design in form development are based on the principle solution. Principle solution is a combination of working principles to fulfill the overall function with first indication of embodiment design [Pahl & Beitz 1996]. One of the well-known strategies related to the principle solution is the methods of quantified structure. According to Tjalve’s [1976], the quantified structure brings us to a level in product synthesis where we can open solution space by varying the way to realize the solution (see also Figure 4). The quantified structure is a method of engineering design which uses variation to determine number or extent of element: to calculate or express the number, degree, or amount of element within a system or organization made up of interrelated parts functioning as a whole. However, the method of quantified structure does not encourage for aesthetics considerations related to subjective, emotional and qualitative form experiences.

## 2.2 Relevance of product semantics for form development in automotive design

From our point of view, supplements such as product semantics to the method of quantified structure are important for automotive design. Therefore, we will give a short introduction to aesthetics and to methods used to evaluate subjective, emotional and qualitative aspects of product design called semantics aspects.

Historically, aesthetics has been defined as the science of “sensuous knowledge,” meaning the knowledge one obtains through the senses, in contrast to the knowledge one obtains through the mind, the subject of this science is beauty and ugliness [Monö 1997]. Moreover, a definition more commonly used in modern days is that “aesthetics deals with the nature of beauty, art and taste and with the creation and appreciation of beauty.” Appreciation of aesthetic values of visual form is part of the science of perception psychology.

The perception of Gestalt is central in the appreciation of visual appearance in automotive design. Gestalt is an arrangement of parts which appears and functions as a whole that is more than the sum of its parts [Monö 1997]. The quality of the whole as being more than the sum of its parts’ means that form, color, material structure are not introduced into the whole as isolated factors. A product can be seen as a kind of trinity within the limits of an economic/ecological circumference. In design work we can speak of a technical whole, an ergonomic whole and a communicative whole and still mean the same totality (see Figure 1).



**Figure 1. A product can be seen as a kind of trinity within the limits of an economic/ecological circumference [Source: Monö 1997]**

In presenting a psychological view of aesthetics appreciation, it represents a mode of form perception, which is not determined by semantics interpretation.

There are several methods for the analysis of designer semantics interpretation [Wikström 2002]. The *semantics differential method* for the analysis of the meaning of objects; wherein the meaning of things is said to lie somewhere within a three dimensional semantics space. The position of the meaning of an object within the semantics space is determined through the evaluation of the object’s grade of fulfillment of adjectives describing desired or non desired qualities. The evaluation is done using a Likert scale (see Table 1).

**Table 1. Adjective pairs connected to a Likert scale and graded by designer x and z**

Adjective	3	2	1	0	1	2	3	Antitheses
Good	x	z						Bad
Modern				x	z			Traditional
Feminine			x	z				Masculine
Stable				z		x		Unstable

The adjective pairs used in the Likert scale are categorized into evaluation, potency and activity factors through a factor analysis. These three factors constitute the axes of the three dimensional semantics space. The values given by the designer to each adjective on the Likert scale defines the product's position within the three dimensional semantics space. Placed in the semantics space, the product meaning can be compared with competing products' meanings, or with a concept of a product with the perfect meaning.

The *product semantics analysis* [Wikström 2002] is structured upon three of Monö's four semantics product functions; *identify*, *describe* and *express*. It is a tool for describe users' emotional and cognitive requirements for a product, and assessing whether these requirements have been met in products or product concepts. The quality of a product's semantics functions *to identify purpose and use* and *to describe function* can be measured by four parameters; intelligibility, response / handling time, correctness and insecurity.

For the analysis and evaluation of the quality of a products semantics function *to express*, the use of semantics word scales is suggested. These are similar to the ones used in semantics differential. It seems that product semantics present relevant supplements to methods such as the quantified structure since it allows opening solution space related to quantitative and qualitative decision-making in the modern form development of automobiles.

### 2.3 The modern form development process of automobiles

The use of the method of quantified structure is an important element in the modern form development processes. However, today the development of technology enables form creation to be expanded to various perspectives like different aspects of aesthetics. One of the latest methods of the modern form development process of automobiles based on the aesthetical dimension is the use of morphing techniques, which can be considered as an enlargement and merging of the "Old Masters" methods with insights from cognitive psychology and the arts with the goal to open solutions space.

The uses of morphing techniques can solve certain aspects of problem-solving within the frame of the form development process. The word "morphing" comes from the compound word *Metamorphosis* of Greek origin. *Metamorphosis* is composed by two words - *meta* and *morphosis* which means the changing way in form of structure. We commonly apply the word morphing as an abbreviation of *metamorphosis* [Chen & Parent 1989]. Morphing usually indicates a special effect on transformation between two images applied in movies or animations. It is most commonly applied in cross-fading techniques to achieve the transformation of one thing into another in films. For acquiring smooth distortion in the morphing process, marking the appropriate corresponding points and vectors between target images is essential.

The shape creation method called shape averaging is used in the development of automobiles. Shape averaging could produce a series of novel shapes between two typical shapes representing different meanings. It is hypothesized that the average results are useful for predicting trends in form, or for extracting stereotypes from a group of related shapes. The technique can be used to create new forms by blending general features of existing unrelated shapes. The algorithms of shape averaging could extract the mean, median and mode forms from the average shape [Chen & Parent 1989]. Figure 2, shows the blending results between car shape and teardrop shape at different weighted averaging ratios.

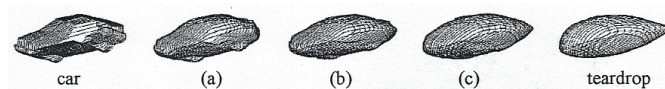
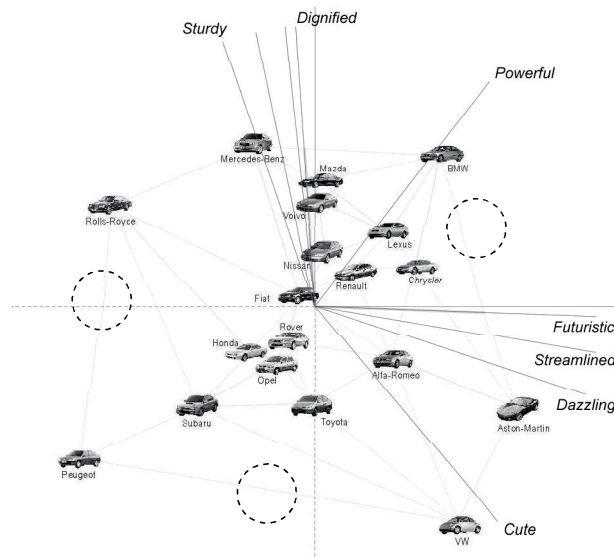


Figure 2. Weighted averaging shapes from a car and the teardrop shape under ratios of (a) 70/30, (b) 50/50, and (c) 30/70 [Source: Chen and Parent 1989]

For understanding how product shapes evoke affective responses, Chen et al. [2003] conducted a survey to evaluate the affective characteristics of each of the product shapes related to the product semantics analysis above. Semantics itself describe users' emotional and cognitive requirements for a product, and assessing whether these requirements have been met in products or product concepts [Wikström 2002].

A perceptual map of automobile shapes was constructed for further study of relationship between automobile shapes and the affective responses. Nineteen representative automobiles and seven adjectives were chosen for analyses. Using a multidimensional scaling program (MDPREF), they constructed the perceptual map. They also used a preference – mapping program (PREFMAP) to determine the location of the vector corresponding to each adjective in the perceptual map, Figure 3.



**Figure 3. Perceptual map of 19 representative automobiles and 7 representative adjectives [Source: Chen et al. 2003]**

In the perceptual map, if two adjectives look similar, then the position of these two aspects will be closer. On the other hand, if two adjectives look dissimilar, the corresponding points will be further away from each other. Observing the perceptual space of nineteen automobiles and seven adjectives, the researchers found that there are many empty spaces (indicated by dotted circular lines). How can we fill up the map and predict the unknown new form at a specific position?

The values determined out of perceptual mapping, such as futuristic, streamlined, dazzling, etc. should form the variables for the morphing technique.

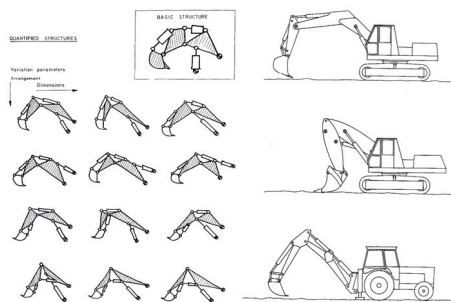
This can be done by developing an algorithm that works on the characteristics of the gestalt such as X, Y, and Z. Reverting to the “Old Masters,” the method of quantified structure is also an important element in the modern form development processes. However, semantics should have been more emphasized and acknowledged as a valuable asset complementary to the quantified structure approach in the generation of the overall design. A frequently used method in the modern form development process of automobiles based is the use of morphing techniques, which can be considered as a valuable tool to enlarge and integrate the “Old Masters” methods with insights from cognitive psychology and the arts. This integration should also enlarge the already opened solutions space.

Similarly to the quantified structure approach, a semantic algorithm should be developed to create new

forms based on values out of perceptual mapping. The following case example shows a quantified structure approach according to the practice of the “Old Masters” as well as the modern form development approach based on morphing techniques. The example does not show a direct connection between use of quantified structure method and morphing to facilitate modern form development. However, this does not mean that the use of quantified structure is irrelevant in the modern form development process of automobiles. The modern form development addresses the need and future possibility of adapting the method of quantifying engineering structures to a semantic-based form generating structure. This form generating structure should enlarge the solution space and bring us to a level in product synthesis where we can move from one principle solution to another solution related to form development.

### 3. Case examples

This section describes how the strategies and the methods of quantified structure are used by the “Old Masters” of engineering design and modern form development of automobiles. The “Old Masters” of engineering design considered form development in design based on quantified structure that enables us to realize principle solutions. It is based on the variation of relative arrangement - number and dimensions. Tjalve [1976] and Hubka & Eder [1982] stated that quantified structure is used from two points of view.




**Figure 4. Quantified structures for an excavator [Source: Tjalve 1976]**

They differ between the elements in which the functional connection can either be included or not. If these functional connections are ignored, the structure variation method gives a number of suggestions for a very rough construction of the product. If the functional connections are included, we get a definite further development of the basic structure, with the aim of optimizing and specifying the parameters involved. Figure 4 shows some quantified structures for an excavator and demonstrate how three of these are employed in existing excavators.

The functional connection between the most important elements is expressed in the basic structure, most often in some sort of sketch showing the principle of the design, where commonly accepted symbols for known elements (machine, hydraulic, pneumatic, electric symbol, etc) are used.

As long as this sketch expresses the basic structure, it is exempted from any definite dimension of form. However, it may be the starting point for a series of quantified structures built on the structure variation method with the relative arrangements and dimensions as parameters for each separate element in the basic structure.

**Table 2. The modern form development of automobiles based on quantified structure using morphing techniques [Source: Chen et al. 2003]**

Products	
Adjectives	Cute                      1                      0                      1                      Powerful

In modern form development process of automobiles, the use of quantified structure is still significant. The modern form development brings us to a level in product synthesis where we can move from one principle solution to another solution related to aesthetics.

This is illustrated in Table 2 with a series of shapes that has been obtained by morphing a New Beetle to a BMW [Chen et al. 2003]. A series of new shapes that smoothly interpolate among shapes have been generated by using image morphing techniques. We can see that the path of distribution of the interpolated shapes provides image of how emotional characteristics change in responses to varying shapes. The uses of morphing techniques make the overall form uncover the solutions in relation to the aesthetical form and the solution principle form in parallel.

#### 4. Conclusions

This paper hopes to provide a better understanding about the possibilities and limitations of the “Old Masters” of engineering design for modern form development of automobiles. We found that the “Old Masters” of engineering design consider form development in design based on quantified structure while in the modern form development process of automobiles is additionally related to aesthetics in a broader understanding including product semantics. Thus, the interpretation of the quantified structure approach and product semantic analysis and their connection seems to be appropriate as a result of study. In the product synthesis, design approaches from the two parties are similar as far as the development allows us to move gradually from one solution to another. Future research should investigate the possibility of developing a semantics algorithm to develop a similar structure for “opening the solution space,” similar to the quantified structure approach.

#### Acknowledgement

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**Paper 2**      On the role of formgiving in design.

Abidin, S.Z., Sigurjónsson, J., Liem, A., & Keitsch, M. (2008). On the role of formgiving in design. *Proceedings of E&PDE 08, 10<sup>th</sup> International Conference on Engineering and Product Design Education - New Perspective in Design Education, Barcelona, DS46-1*, 365-370.





## ON THE ROLE OF FORMGIVING IN DESIGN

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### ABSTRACT

This paper discusses different interpretations of the word “formgiving” in design literature. A comparative study has been made between the two main areas of design, industrial design (ID) and engineering design (ED). The main findings are that in ID, the use of the keyword formgiving is related to the artistic visual elements, while in ED the use of this same keyword is related to the engineering principle solutions. In terms of the approaches of formgiving in design, for ID, which is related to art and design, qualitative measurement is the preferred way of documenting the findings, which in this context refers to the quality or type of form. In ED, which is related to technology and engineering, quantitative measures are common. Quantitative, in this context, relates to the quantity or amount of the form. The totality of formgiving can, however, only be examined by using linguistic interpretations. Finally, within these two areas of design, the study illustrates that formgiving can also be influenced by aesthetics features. The aesthetics in this perspective can be interpreted as a study of the effect of formgiving on human sensations. The focus here is on the appearance or the consequence of the form. This differs from most/previous publications which deal with creation and appreciation of the form.

*Keywords: aesthetics, design, formgiving, shaping*

### 1 INTRODUCTION

In the design process, the most crucial part in making the product appearance outstanding is during *form* creation [1]. Form in design means to shape or mould a particular model into a certain state or shape.

For more than 20 years, the word *formgiving* or *form-giving* has been commonly used in Scandinavian countries. According to the Norwegian dictionary, the meaning of “*formgivning*” or “*formgjeving*” is fashioning, molding; industrial design. Previously, most of the design authors used the word “shaping” in the same meaning as *formgiving*. Moreover, available Standard English dictionaries do not interpret the meaning of *formgiving*. But yet, it seems that the use of the word *formgiving* has become popular among many design authors when discussing design practice.

*Formgiving*, when used in engineering design, relates sometimes to a specific phase in the design process: the part in which a solution-principle is developed into a materialized design [2]. Here, the emphasis is on the embodiment; the determination of form and material, as well as the process of bringing both in line with each other.

In this paper, we intend to provide some viewpoints about *formgiving* based on the following structure: (1) introduction; (2) elements and properties of product form; (3) the comparative study of *formgiving* based on different approaches in design; (4) discussion; and (5) conclusion. The aim of this study is to uncover the meaning of the keyword of *formgiving* and demonstrate how its role contributes to the product appearance.

## 2 ELEMENTS AND PROPERTIES OF PRODUCT FORM

In Industrial Design (ID), the creating of form(s) during designing involves the understanding of use of basic entities of *visual elements* (VE) such as point, line, plane or surface, and volume (see Figure 1), as well as the organization rules and principles for putting together the composition or structure [3]. VE form part of the attributes of form that create tone and texture, imparting visual interest and meaning. Their importance becomes evident through their use in generating images and form(s) that are both two dimensional (2D) and three dimensional (3D).

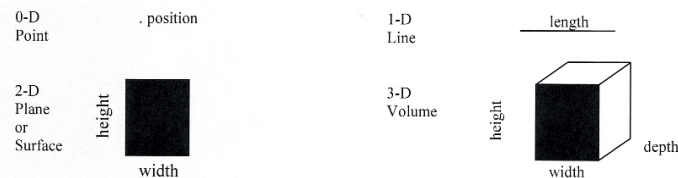


Figure 1 Four basic visual elements (Akner-Koler, 2000, p.7, and Muller, 2001, p.80)

According to Wallschlaeger [4], defining and relating the application of VE to visual studies is sometimes most challenging since the term(s) can be interpreted and used in different ways, not only in art and design but in other disciplines, especially engineering, mathematics, physical sciences, and the humanities. To give a clearer picture, the mathematician may think about defining words such as point, line, plane or surface, and volume in abstract terms. In geometrical terms, a point has no dimension. It is only attributed in defining a location or position. A line is thought as a point in motion within space, and it has only one dimension length. A plane or surface is a flat surface bound by lines that has the attributes of length and width, but no depth. Volume, in conceptual terms, is described as a plane in motion of a direction other than its inherent direction. For example, a 3D form is derived from and enclosed by planes that have a position in 3D space.

In Engineering Design (ED), the creating of form(s) can be based on several form generation models. Many of these models are based on *principle solutions* such as the problem-solving process [5], and synthesis–analysis order [6]. The problem-solving process is an activator assisting in the creative process that in a general sense encompasses a variety of activities with widespread applications [1]. This process is found in a form as either a structured and unstructured way, and can also result in the generation of form(s). The problem-solving process also considers the design activity as a problem to solve [5]. Besides, synthesis-analysis is considered here as a compound activity as it involves search, exploration and discovery of design solutions, and composition and integration of these solutions [6].

The use of the method of quantified structure is common in ED in the creation of form. Tjalve [7] states that quantified structure is used from two points of view that differ by whether or not the functional connections between the elements can be included. If

these functional connections are ignored, the structure variation method gives a number of suggestions for a very rough construction of the product. If the functional connections are included, we get a definite further development of the basic structure, with the aim of optimizing and specifying the parameters involved. In order to see the gap in different uses of meaning of *formgiving* in ID and ED, a comparative study has been carried out.

### 3 COMPARATIVE STUDY OF FORMGIVING BASED ON DIFFERENT APPROACHES IN DESIGN

Two experts in representing different views on design education have been selected as case examples in this paper. The first, Cheryl Akner-Koler (Akner-Koler), has been educated in ID [3], and the second one, Wim Muller (Muller), has been educated in ED [2].

Akner-Koler states that the evolution of form can be done through several stages such as join (u-joint, o-joint), intersectional (core), divide (accordance, discordance), adapt (assimilate, dissimilate), merge (converge, diverge), distort (conform, deform) as well as organic or geometric (convexo-concave, concavo-convex).

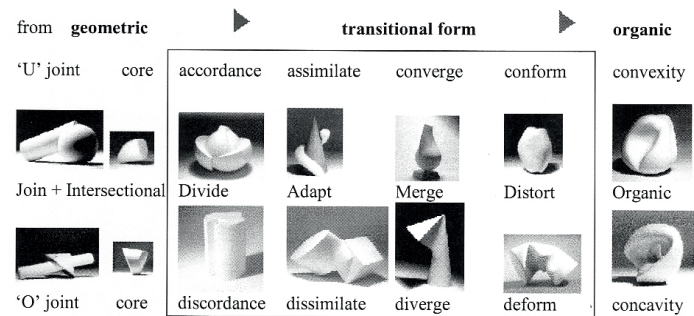


Figure 2 Form evolution based on visual elements by Akner-Koler (2000, pp.46-47)

The evolution can be expanded using the manipulation of VE until the designer is able to select the appropriate form and use it for detailing and further refinement until the embodiment phases (see Figure 2). This is the sample of form evolution, 3D form model, bringing geometric structures to organic structures created by Akner-Koler. The first horizontal axis presents a sequence of geometrically derived forms that gradually take on organics quality of convexities and concavities. The second axis expands the model in the vertical dimension to include a bipolar spectrum at each stage. The vertical dimension opens up a dichotomy (separation of different or contradictory things) between congruent (with same form) and incongruent properties in relation to the original features of the geometric form. This makes it seem as if form has been developed throughout qualitative structure (based on the quality or character of form).

According to Muller, in the beginning of form generation phase, designers have indicated that the core of design is founding the transition of function into form, and then, this transition marks the form creation phase through the evolution process. The difficulty of the transition and the great challenge for designers is the fact that in principle many solutions are possible and, in addition, not one single correct solution can be determined for the fulfillment of a technological function.

Many different viewing positions are required to get an impression of formal material elements and the plasticity of complex touch form. However, Muller illustrates that

form evolution is developed from the primitive object through the *topological*, *typological* and *morphological* levels, and it does not only refer to exterior geometric form, but also to the *physico-chemical* form or material composition of an object.

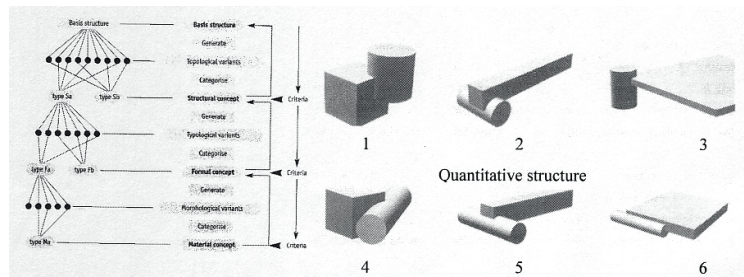


Figure 3 Form evolution based on principle solutions by Muller (2001, p.281)

Muller, in one part of his example, believes that different form compositions act as the starting point for an exercise in “form integration.” Starting from a composition, an integrated whole has to be obtained by means of additive and/or subtractive transformation by the manipulation of principle solutions through quantitative structure (see Figure 3). This is similar to the approaches of Tjalve [7] for the quantified structure. For Akner-Koler and Muller, understanding and perceiving the potential expressions of form that are embraced in the “Form evolution” model, a broad aesthetical attitude to *formgiving* can be developed. The organizational capacity that is represented through form and space offers this pluralistic structure that can create coherency out of seemingly disparate demands.

#### 4 DISCUSSION

An analysis based on the approaches by Akner-Koler and Muller has provided more similar patterns rather than differences toward the meaning of *formgiving* as form creation (see Section 3).

##### 4.1 Design inspired and measurement approaches

While *formgiving* requires design-inspired approaches, understanding engineering principle solutions can make the design process easier. Design can be based on patterns in nature and on mechanical functions. It can also be based on other factors such as the use of code of language, semantics, symbols, reproductions, or the individual choices of the designer [7, 8]. In terms of measurement approaches for *formgiving* in design, Akner-Koler who relates to art and design prefers qualitative measurement for documenting findings, while Muller who relates to technology and engineering, quantitative measures are more commons.

##### 4.2 Formgiving related to the aesthetics

Current design solutions require consideration of *aesthetics* features all the way from form surface appearance to making the form marketable. The aesthetics goal of a design concept toward *formgiving* is mainly interpreted as a *natural* (e.g., beautiful or ugly) form and as a creation for spatial condition. Aesthetics in this context mean the study of the effect of product gestalt on human sensations [8]. Product gestalt, in turn, is the arrangement of parts which constitute and function as a whole product, but which is more than the sum of its parts.

For Muller aesthetics is a measure that gives the impression that beauty benefits from a high degree of ordering and low complexity; “the simpler, the more beautiful” is what theory tells us. However, besides immediate sensuous responses, aesthetics have always been connected to the function of *linguistic interpretations* like semantics too. Semantics includes the dimension of semiosis, and the study of semantic aspects of sign systems, the production of meaning by signs, as well as their interpretation. The term “Semiosis,” was coined by Charles Sanders Peirce as a performance element involving signs. Semiosis means relationship between what a sign refers, the representation, and the understanding of the sign in the “mind” of the sign receiver. Akner-Koler in 2006 in her article about “*Expanding the boundaries of form theory: Developing the model Evolution of form*” tries to relate aesthetics in the development of form, which plays an important role in *formgiving* development. However, her appreciations about the aesthetics seem similar to Muller who is more focused on sensational aesthetics aspects.

#### 4.3 Advantages of *formgiving* development in design education

There are many potential advantages incorporating *formgiving* understanding; and the form development process in design education. Since aesthetics play a major role either in ID and ED, people can correlate *formgiving* with elegance, efficiency, robustness and alertness. When *formgiving* features are incorporated into the layout of modern cars, people are more likely to perceive the car as elegant, efficient, and good function performance. It is important for the final product form.

One example is by applying *animal form* (zoomorphism) to the design. Animal form is now uses in the styling of modern motorcars design [9]. Many animals are highly optimized for fast movement and this produces aesthetics features such as curvaceous, forms, symmetry, wholeness and distinctive body profiles. Here the character of the Cougar animal is mapped onto the Ford Cougar car (see Figure 4) by reflecting to prominent features of the animal face (e.g., Headlamp – Eye). This kind of similarities can also be seen in other models of car such as Jaguar XK, Volkswagen Beetle, etc.



Figure 4 Cougar animal and Ford Cougar car

Since people often associate animals with elegance and efficiency, the use of animal forms in car styling can lead to form with a wide appeal. In addition, the use of animal forms is inherently compatible with functional requirements because of the high level of optimization of nature forms. Instead of animal form, the *nonhumans* form (anthropomorphism) which base its attributes on human characteristics can also been considered as references in the design. It can be built on to become a more specific design when *embodied agents* are designed for specific task and domains like gender, casting, and recasting [10]. Gender is a primary design feature and should be a critical consideration in design of embodied agents. Casting is a means of fleshing out agent personality. Recasting is a means for creating experiences within and across product use. One important question is how we use cannon-animal form and cannon-nonhumans form to visualize ideas?

However, the use of metaphors, meaning, symbols, and signs as influence can transmit *formgiving* to the aesthetical judgment. Furthermore, the use of analysis based on

semantics and semiotics in relation to aesthetics is expected make form able to capture human attention.

## 5 CONCLUSION

In this paper, we conclude that the definition for the keyword of *formgiving* is form creation, and it deals with the concreteness of aesthetical reasoning in the design process. There are three levels of form development in design phase: (1) The early phase, when we question the orientation of the image elements; (2) The middle phase, when we need to consider the type of form in which we format the image elements; and (3) The final phase, when we make decisions that lead to a more detailed picture of the image developed so far. All of these phases involve a well-known transitional process of form evolution. The finding shows that the use of linguistic interpretations is significant as a mean of analysis in order to examine *formgiving*. In terms of the measurement approaches of *formgiving* in design, from Akner-Koler's (ID) art and design perspective, qualitative measurement is the preferred way of documenting the finding. Meanwhile, from Muller's (ED) technology and engineering perspective, quantitative measures are common. Finally, within these two areas of design, the study shows that *formgiving* can also be influenced by aesthetical features.

Our future work will include exploring the notion of qualitative structure and quantitative structure throughout the methodology featuring *formgiving*, in order to understand how it might change the use of the method underlying the designer's way of thinking.

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**Paper 3**      The embodied mind in relation to thinking about form development.

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## The embodied mind in relation to thinking about form development

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### Abstract

This paper explores the notion that form development is fundamentally a process of the embodied mind. Traditional design methodology recommends that we should design by moving from concrete problem descriptions to abstract solution models. The abstract models are then developed towards concrete solutions via functional principles and principle structures. However, in the automobile industry concepts such as bone line and body are used when describing a car. We want to explore whether the designer is using some kind of metaphorical understanding instead of structural principles. A verbal protocol analysis showed that the designer uses his hand to understand product form while drawing it. This leads us to think that mental images interact in some way with action schema to play a part in the designers' apparently intuitive form-giving. This is in agreement with Lakoff and Johnson's proposal that metaphorical thinking is embodied. The results suggest that a closer look at embodied mind theory might be beneficial to understanding some of the apparently intuitive processes of the designer. We propose that such a study may provide us with ways of understanding and facilitating intuitive processes in design.

**Keywords:** *form, tactility, thinking*

### 1. Introduction

The word *intuition* is commonly used when explaining designers work. In general terms, "intuition" is the power or faculty of attaining direct knowledge or cognition without evidence of rational thought and inference [1]. It is a quick process. Sometimes it seems magical and is not necessarily a conscious process. To our knowledge, it is unexplainable, though several proposals exist. We will look at one of these before moving on to the question of how designers use intuition.

There are several directions of theoretical and neurological explanation of creativity and intuition. For our study a point of departure is Mumford and Caughron's [2] commentary to Vandervert et al. [3] which provides broad support for the proposal that creativity and intuition come from the basic motor properties in the brain. "*The cerebellum serves to abstract mental models reflecting patterns of activity and this forms the basis for language*

*development and finally complex metaphorical representations. These models may be either forward (predictive in nature) or inverse (serving to produce automatic responses). Within the theory proposed by Vandervert et al., it is these forward mental models that provide the basis for creative thought in that multiple models, and multiple hypotheses, are activated in novel situations. The combination of these models, which in their view are primarily visual in nature, gives rise to new ideas. These new ideas are subject to both revision, and error-based testing, in formulating a creative idea [2].* Moreover, from trial-and-error we can identify what seems to be a general characteristic of so called intuitive environments or contexts of direct or unmediated engagement – or engaging *atmospheres* [4]. Applying Vandervert et al.'s model to design practice we see that technical function might be understood by the actions of the body. The designer can also work backward from the functions the product is supplying to the user and create representations of internal technical processes. The common term used in the technical development process related to the creation of new design is *form-giving*. Form-giving in design could mean to shape or mould a particular mental model into a certain shape. In industry, it seems that the designer always associates form-giving with the *aesthetics*. The aesthetics element of form should also be explainable as embodied mental models, language and metaphor. Aesthetics here means designed aesthetics, the study of beauty related to effect of *gestalt* design on sensations [5]. Gestalt in design is defined as a totality of form experiences.

Finally, in order to relate something visual to the physical and emotional world, designers must transform a brief and background information into a new idea. The designer generates a gestalt by using language and then transforming it to physical activity such as human gestures or drawings or collages in order to produce a form, and the result of that should be to get a feel for its tactility, activity and experience. Moreover, repeated bodily interactions lead to the formation of image schemes determining the way we understand the world [6], and thus a new design is born.

We have shown that interpretation and understanding of form may stem from embodied mental models. The question is can we harness the embodied understanding of a product by facilitating it? We have conducted an experiment to this purpose, but before reporting on it we will briefly turn to traditional industrial design and engineering for signs of intuition or embodied thinking.

## **2. Thinking related to design activity**

A few “Old Masters” of engineering design like Gerhard Pahl and Wolfgang Beitz, Vladimir Hubka, Eskild Tjalve, and Karlheinz Roth tried to make guidelines and catalogs related to the uses of engineering principle solutions (e.g., functional principles and principle structures) in order to assist designers in generating and developing an idea. However, the concept of intuition is not covered by them in great depth? Only Pahl and Beitz state that “...*good ideas are always scrutinized by the subconscious or preconscious in the light of expert knowledge, experience and the task in hand, and often the simple impetus resulting from the association of ideas suffices to force them into consciousness* [7].” It is apparent that the “Old Masters” way of thinking in the engineering design process is more toward *problem-solving* approaches. Problem-solving approaches are still being used by the designer in engineering design.

According to Simon the problem-solving process considers the design activity as a problem to solve [8]. For him, there are different variants, but all problem-solving process models can be described as a gap between an Observed State ( $S_o$ ) and a Desired State ( $S_d$ ),  $S_o \neq S_d$  given a set of constraints. The procedure to apply in order to get to the desired state may be unknown. An observed state and a desired state may need to be refined and can change over time. Most of problem-solving process is related to three stages; (1) *Intelligence* (to understand an observed

state, a desired state, the constrains and define them), (2) *Design* (to generate solutions), and (3) *Selection* (to decide: (a) to redefine the problem which means going back to intelligence, (b) to refine or find new solutions which means going back to design, and (c) to choose one solution which involves finding evaluation criteria). However, problem-solving does not provide any tool or concepts for intuition.

Beside problem-solving, *synthesis* is also considered an apex of design activities. Synthesis is considered here as a compound activity as it involves search, exploration and discovery of design solutions, and the composition and integration of these solutions [9]. The definition of synthesizing in design activities is the result of abstracting and generating design concept(s) and structuring concepts to form a whole. This process may be modeled on two axes labeled abstract/concrete and undetailed/detailed (see [10, 11]). Modeling are activities used to represent the design solutions in terms of their function and/or structure so that their performance in terms of behavior can be analyzed and evaluated through testing in a real world of full-size or scale models, or simulated in possible worlds.

The designer views designing as a conversation with the materials and constraints conducted through the medium of drawing. The process is characterized as a reflective conversation with materials whose basic structure, seeing–moving–seeing, is an interaction of designing and discovery (see [12, 13]). For instance Schön states that “...*the designer sees what is there in some representation of a site, draws in relation to it, and sees what has been drawn, thereby informing further designing.*” Lakoff and Johnson state that the most fundamental *metaphor* Descartes uses is the commonplace “Knowing is seeing” metaphor. There are two domains in this metaphor the visual domain and knowledge domain (see Table 1). The “Knowing is seeing” metaphor defines the core of a *folk theory* about how the mind works that is widely shared in our intellectual operations [14]. What Schön is saying is basically the same thing. Designers use visualization as a means of triggering new insights into the material they are working with. The insights may come from schemas or mental models, but they may also be analogies to something else.

**Table 1. Knowing is seeing (from Lakoff and Johnson [14])**

Visual domain		Knowledge domain
Object seen	→	Idea
Seeing an object clearly	→	Knowing an idea
Person who sees	→	Person who knows
Light	→	“Light” of reason
Visual focusing	→	Mental attention
Visual acuity	→	Intellectual acuity
Physical viewpoint	→	Mental viewpoint
Visual obstruction	→	Impediment to knowing

Designers use metaphor as a strategic approach during design activity. A metaphor is a figure of speech in which a word or phrase literally denoting one kind of object or idea is used in place of another to suggest a likeness or analogy between them. For example: the “conversation is war” metaphor or “time is money” metaphor. This method is employed visually as well, for instance in collages or semantic charts or as explanatory graphics in software user interface design.

The human body metaphor is generally used in the car industry. Designers often talk of “hard muscles” under “soft flesh,” referring to the conceptual differentiation between kinds of underlying structure that state the characteristic shapes of the car from the merely cosmetic surface [15]. The concept of a solid structure under the surface of the car body is also called “a bone line” that defines the gestalt design of the car.

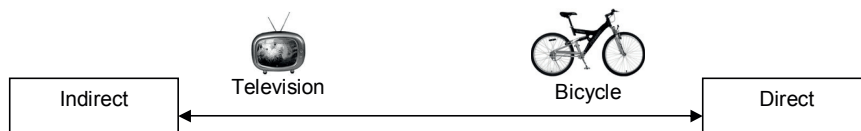
This way of thinking is opposite to the approaches from the “Old Masters” of engineering design. Their approaches are structured within concrete problem descriptions to abstract solution models. But yet, it seems that there are possibilities for using intuition as an alternative to engineering methodology.

### 3. Thinking with the embodied mind: is intuition an alternative to engineering methodology?

Since the “Old Masters” of engineering design did not give rise to a way of research related to the use of intuition during the design process, this may have limited the designer’s way of thinking to associate ideas between the mind and the body. However, Lakoff and Johnson’s statement about the notion of intuition in the design world seems to provide an option for another way of thinking. Even though intuition is *fuzzy* in current design practice, it still can be considered as an alternative to improve the design process.

In daily life, humans like to use the images in words such as ‘beautiful’ and ‘ugly’ to invoke moods in an object or a product. However, the psychological problems of focusing the image or feelings for a product are full of fuzziness and uncertainties. Traditionally, this mental recognition problem with high fuzziness is solved by the designer using his/her intuitive feeling as well as experience and inspiration from artistic work, and habit. However, designers from engineering always struggle to find the right methodology for this kind of fuzziness in design.

Based on the above reason, the study of intuition related to engineering methodology has attracted many engineering designers lately. Instead of quantitative methods which involve the measurement of quantity or amount, qualitative methods which involve the measurement of quality or kind have been used in design research [16]. Most engineering designers attempt to carry out design research focused on the combination of human physical activity and mental activity. They also explore a lot of possible ways of conducting experiments connected to the study about intuition. Some of them try to use existing instruments (equipment for measuring and recording data) from other disciplines [17] such as neurology in psychology, cognitive science, etc and matching those with the engineering instruments in order to study the language of intuition in design. Engineering methodology has failed to apply these tools to understand the cognitive-psychology and the neuro-psychology of the designer through experimentation. Instead, most of them discovered interesting findings during this kind of experimentation based on personal experience.



**Figure 1. Indirect-direct continuum user interfaces (adapted from Hoff, Øritsland, and Bjørkli [18])**

In order to identify the elements that constitute the “goodness” of personal experience in the language of intuition, we refer to an experiment carried out by Hoff, Øritsland, and Bjørkli [18] on indirect-direct continuum user interfaces (see Figure 1), in which indirect (or “second hand”) information refers to activities that tap explicit reasoning; and direct (or “first hand”) experience refers to perception-action cycles. Perception-action cycles again, refer to skill-based knowledge, in which “knowledge” refers to knowing *how*, as opposed to knowing *what*. The indirect interface requires the user to explicitly reason about information and interface,

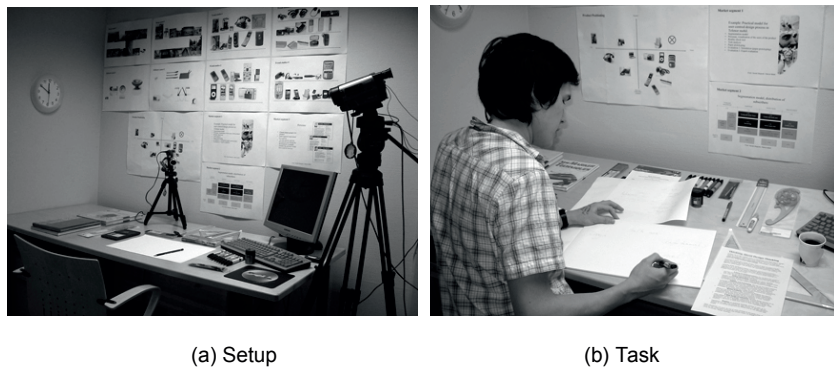
one such example being the user interface information in the television. The domain of indirect interfaces represents a range of logical information, such as pictures, texts, and numbers that can be measured quantitatively. Meanwhile, the direct interface requires the user to employ skill-based, tacit knowledge, for example, the skill of riding a bicycle. The domain of the direct interfaces provides practical problems such as how to react and balance the body of human when riding a bicycle and it can be measured but no measurements directly convey the feeling you need to master bike riding. Qualitative methods come closest because they can communicate in expressive language.

Since intuition is related more to qualitative than quantitative qualities, we believe that the experiment related to the empirical study of intuitive form development in design should be conducted using qualitative method. The purpose is to see how perception-action cycles and explicit reasoning interact between subject, and mental representation.

#### 4. Empirical study of intuitive form development

In order to empirically explore intuitive form development we conducted an experiment. A fourth year student from Norwegian University of Science and Technology (NTNU) (called hereafter the designer in short) kindly agreed to participate in this experiment. The controlled experiment was conducted based on observation using “Verbal protocol analysis.”

Verbal protocol analysis (VPA) is a method of bringing out into the open some of the cognitive processes of designers. Of all the empirical, observational research methods for the analysis of design activity, VPA is the one that has received the most attention in recent years. Ericsson and Simon are the original disseminators of the VPA method [19]. The pros and cons, as well as the techniques for VPA, are described in-depth in their work. In terms of the validity of the experiment the verbalizations in the VPA indicate the inputs and outputs to the processes rather than the processes themselves. This is parallel to the research technique for design by Cross, Christiaans, and Dorst where they discuss the validity of VPA: The purpose of observation is to see any interaction between the mind and the body [20].



**Figure 2. Setup and task of verbal protocol analysis**

The basic strategy of VPA involves getting people who are doing something to verbalize their thoughts and feelings as they do whatever they are doing. VPA also maps how users describe themselves as interacting with objects. Both the verbalizing and interaction are rooted in language and cannot be separated from the respondents’ linguistic use of objects in communication with others [21]. This is supported by Lakoff and Johnson, also Talmy and Regier, that the study of spatial-relation concepts within cognitive linguistics has revealed that there is a relatively small collection of primitive images schemas that structure systems of

spatial relations in the world's languages [22]. Their examples, without the full detail given above: part-whole, center-periphery, link, cycle, iteration, contract, adjacency, forced motion (e.g., pushing, pulling, propelling), support, balance, straight-curved, and near-far.

In this experiment, the studio setup (a) and task (b) are based on an artificial situation (see Figure 2). The designer has been provided with the brief of a project. The title of the project is "Design an Urban Scandinavian PDA (Personal digital assistant) adaptable to the needs of trades and profession."

In front of the subject, there are five standard posters [23] as references: (a) Image panel; (b) Influence panel; (c) Trend studies; (d) Product positioning; and (e) Market analysis.

Sketching is used as means of analyzing design activity (see [24]). This is because research related to design and thinking regards sketching as a means to stimulate creative thought [25].

We have conducted the experiment based on the synthesis of design activity (see the experiment by Lloyd, Lawson, and Scott [26]). There are three levels of abstractions that have been looked upon. The first level is the *abstract* level, followed by the *semi-concrete* level, and finally the *concrete* level. Abstract is the level when we question the choice and the orientation of the image elements; Semi-concrete is the level when we need to consider the type of form in which we format the image elements; and Concrete is the level where we make decisions that lead to a more detailed picture of the image developed so far. The process of design itself has different levels of abstraction. However, three levels are commonly in use and three are sufficient to get fruitful information in an experiment related to the design process.

During the designing process, from abstract to concrete level, the designer uses verbal expression as a way of communicating on what he is thinking. To identify relations between the designer's verbal expressions and body reactions, we analyzed the VPA, searching through the episodic data for signs of body use in the generation/discovery of design solutions (see Table 2). Analyzing the data, episodic intuition elements were discovered. We also identified examples of body reactions in episodic data, not linked to intuition, but still very important for the generation/discovery of the design solutions. The reaction of the body seems to automatically occur when the designer uses metaphor in explaining something visual. We found that few keywords based on verbal expression give a sign to body reaction. The words are: I think, then, erm, maybe, going, can be, fix, have, many, attachment, holding, could be, loose, need, numbers (like ten by fifteen), fold up, open up, I want, sliding, using, yeah, reminds, I like, but, seems, this idea, more, able, type, and whether.

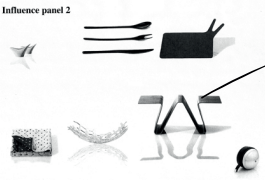
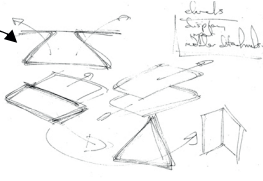
**Table 2. Verbal expression and body reaction**

Protocol time	Episode of verbal expression	Sign of body reaction
00:01:23	...somewhere that <i>I think</i> need can be served existing PDA...	Eyes look at the poster
00:02:39	...specific profession and <i>then</i> take it back...	Hand move forward and backward
00:03:42	... <i>erm</i> ...civil service...	Shaking the head
00:07:45	... <i>maybe</i> the regular function of PDA	Hand twist
00:09:35	... <i>we going</i> to have a device... <i>we have</i> main unit... <i>we have</i> a separate unit that <i>can be</i> attached... <i>can fix</i> the module idea...this <i>can be</i> connect everything <i>I think</i>	Left hand stand still at upright position
00:11:13	... <i>we have</i> many interfaces...and <i>many</i> input device...and the modular <i>attachment</i>	Hand point to the poster
00:12:31	... <i>holding</i> and <i>could be</i> ...product screen	Left hand open
00:13:48	...a little bit too <i>loose</i> at the moment	Hand twist
00:15:48	...looking at this here...thinking about a device...fit	Hands open and close

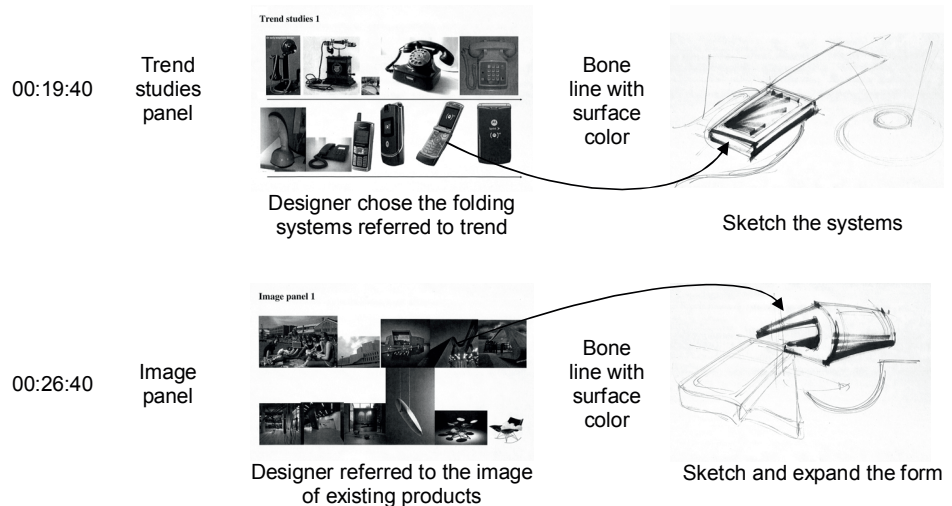
	in the <i>need</i> of a rugged product...durable outer casing, to reveal the function something inside...I <i>need</i> the key elements of screen or display and modular <i>attachments</i> ...	together
00:17:40	... <i>ten by fifteen</i> ... <i>maybe</i> ... <i>maybe</i> having a device...	Hand like holding something
00:18:14	...so, I <i>want</i> a device can <i>fold up</i> ... <i>open up</i> ...and can also support itself...independence of the user...	Hand open and close together and eyes look at the poster
00:19:25	... <i>sliding</i> component <i>maybe</i> ...	Hand move forward and backward
00:19:36	...hand on device thinking... <i>using</i> one...	Hand like holding something
00:23:38	... <i>yeah</i> ...I <i>think</i> what Scandinavia is...less is more...	Hand move forward and backward
00:24:00	...that <i>reminds</i> me the red vessel...	Hand point to the poster
00:24:30	... <i>maybe</i> physical display... <i>laser</i> projection...display element...	Hand like holding something
00:30:43	...I <i>like</i> the shape... <i>but</i> I <i>need</i> ... <i>but it seems</i> doesn't fix the function anyway...something <i>maybe</i> more aesthetics and <i>more</i> ergonomics I <i>think</i> ...	Hand like holding something
00:32:02	...I <i>think</i> this <i>could be</i> a screw device... <i>maybe</i> not...I just thinking...I don't think...	Hand like holding something and finger move
00:34:22	... <i>this idea</i> ...I <i>think</i> ...	Hand like holding something
00:35:06	... <i>able</i> to <i>type</i> a data...	Hand like holding something and another hand like push a button
00:43:32	...I am thinking <i>whether</i> to <i>have</i> a screen...rectangle...extends all the way...two key button like a control function...	Hand like holding something

In the observations at the semi-concrete level, we found that the designer communicates with the information to define a concept. The designer is thinking and exploring possible design solutions to expand form variation. At the same time the designer looked at visual images in front of him to justify the final appearance of product. We found that the concept of a solid structure under the surface of the product body (also called “a bone line”) defines the gestalt design of the product (see Table 3). This seems consistent with Monó's description of form as a part of gestalt, for him gestalt is an arrangement of parts which appear and function as a whole that is more than the sum of its parts [27].

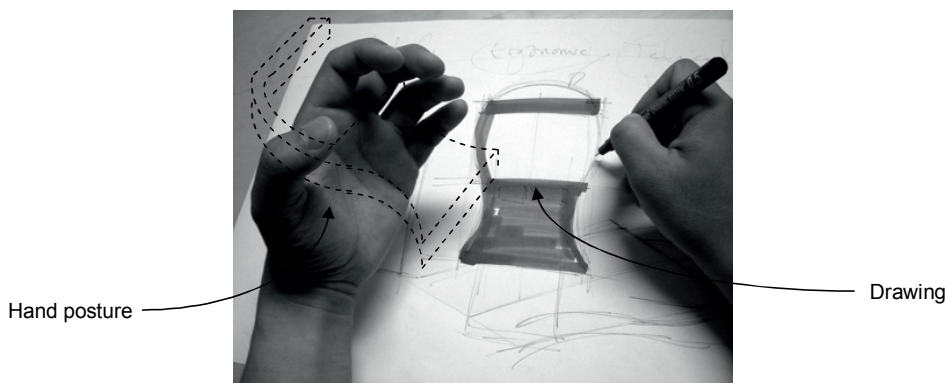
**Table 3. Image interaction design at the semi-concrete level**

Protocol time	Episode			
	Interaction	Images	Features	Result
00:15:48	Influence panel	 <p>Influence panel 2</p> <p>Designer copied the existing form</p>	Bone line	 <p>Sketch the new form profile</p>





Based on an in-depth study and detailed observation at the semi-concrete level (see Figure 3), we discovered that the designer frequently used an empty handed gesture to visualize the expected form.



**Figure 3. Designer use empty handed gestures to visualize the expected form at the semi-concrete level**

In order to make the product explicit, at the concrete level, we also discovered that the designer continued with the use of hand posture activity in order to get a feeling for the tactility (responsiveness to stimulation of the sense of touch). Looking at the image, when the designer is drawing, the image is embodied through the movement of the hand to get the size of the imagery.

The imagery in question is embodied in the gestures that universally and automatically occur with speech. Speech and gesture occupy the same time slices when they share meanings and have the same relationships to context. It is a profound error to think of gesture as a code or “body language,” separate from spoken language.

## 5. Conclusions

Based on the discussions and the empirical study of intuitive form development in design, we drew one major conclusion. The mind and the body of the designer play a role together in design. We observed that design is slow at the beginning of the abstract level and energetic at the semi-concrete level and concrete level with much development and exploration. At the semi-concrete level and the concrete level it is shown that the designer explores existing designs based on the posters in front of him by redrawing them. We hypothesize that this activity develops a stronger embodied understanding of the form. The designer uses his empty handed gestures to feel and describe form in relation to tactility. We can also hypothesize that other embodied forms, movements and tactile properties are being called on mentally, but are not visually apparent in this experiment.

The in-depth studies in this experiment show that the application of hand activity in design seems important to the designer in order to understand and visualize form related to the image in the mind. Similarly, in the automotive industry, designers use tape drawing or clay to balance a form and to adjust the proportion of the design. Based on our finding we assume that mental images interact with action schema and play a part in designers' apparently intuitive form-giving. It is also proven that the designer wants to feel the form of design in relation to the tactility. In addition to this finding being relevant to the manual process in design, in our opinion the finding also seems significant to the development of the Computer Aided Design (CAD) systems and software for the designer. When using CAD it might be beneficial for the designer to somehow feel the tactility of the form while designing.

This result is in agreement with Lakoff and Johnson's proposal that metaphorical thinking is embodied. In order to facilitate this form of thinking the design process should provide real size modeling with the body. Finally, for further research the results suggest that a closer look at the theory of embodied mind might be beneficial to understanding some of the apparently intuitive processes of the designer. This can be explored in further research on the embodied mind in the application of CAD. We propose that such studies may provide us with ways of understanding and facilitating intuitive processes in design.

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## **Paper 4**

### **Designers' perceptions of typical characteristics of form treatment in automobile styling.**

Liem, A., Abidin, S.Z., & Warell, A. (2009). Designers' perceptions of typical characteristics of form treatment in automobile styling. *Proceedings of Design and Semantics of Form and Movement, 5<sup>th</sup> International Workshop on Design & Semantics of Form & Movement (DeSForM 2009), Taipei*, 144-155.



# Designers' perceptions of typical characteristics of form treatment in automobile styling

## Abstract

Automobile styling is a complex discipline where the designers' recognition is determined by visual elements of the car and characteristics that establishes the expressive properties of the overall form. The objective of this study is three-fold. The first objective is to find out how recognition is formed by visual elements of the car. The second objective is to determine what form characteristics are important for creating expressive properties of product form. The third objective is to find out what words are generally used by designers to describe expressions of car designs, specifically based on a word list and images of cars. This has led to the following implications:

1. The identification of general perceptions of car designers, which are most relevant for automobile styling.
2. The development of an understanding on how these perceptions, expressed as adjectives, influences or can be used as a basis for selecting a range of factors and characteristics typically used in car design, such as form features, form elements, and form principles.
3. The exploration of applying selected bi-polar adjectives as spectra for morphing.

The study has shown that there are valid correlations between selected designers' perceptions and form elements/car components of an automobile. This justifies the search on how these selected designers' perceptions can be used as a foundation for automobile styling.

## Keywords

Automobile Styling, Car Components, Designer Perceptions, Form Elements, Form Features.

## 1 Introduction

Because of Modernism's paradigm about functional problem solving and "form follows function", styling has been relegated to an unnecessary evil. However, styling plays a strategic, communicative role in design, especially for product differentiation when an industry moves into its mature phase [1, 2].

In the matured automobile market, designers are challenged by differentiating car models based on a common platform; the task is usually two fold: at corporate brand level, the designer needs to continue and strengthen a specific brand image; and, at the product brand level, the designer seeks to create novel and distinct characters for a car model. The brand and model image can be manipulated by design via the use of visual elements, which consists of design features to identify a brand and design features for specific models to emphasize individuality [3, 4].

Karjalainen's work [4], noted that explicit visual references are embedded in the design features designers implement with the intention to be immediately perceived and recognized. For example, Volvo has defined explicit design cues that are used consistently over their entire product portfolio. These include the strong 'shoulder' line, the V-shaped

bonnet, the characteristic front with soft nose and diagonal Volvo logo, the rear with its distinctively carved backlight, the flowing line from roof to boot-lid, and the third side window. Previously, Warell [5] developed qualitative methods to identify and assess such characteristic elements, which may have syntactic or semantic roles in product design.

In daily life, people like to use image words based on the aesthetic features such as 'beautiful' and 'ugly' [6] to invoke moods in an object or a product. However, the psychological problem focused on the fact that image perceptions or mental feelings for a product are full of fuzziness and uncertainties. Traditionally, this mental recognition problem with high fuzziness is usually solved by the designer based on his/her intuitive feeling, experience, inspiration from artistic works, and habit. Later these intuitive feelings were formalized and structured through Kansei Engineering where consumer feelings and demands were used to design a new product [7].

Within the field of automobile design, fuzzy set theories and consumer-oriented Kansei engineering techniques were applied to analyze the results of consumer surveys and determine the relationships between image and shape-regulating words and car styles [8]. Also, fuzzy set theories in conjunction with weighted mean and weighted generalized mean methods have been used to merge multiple beta-spline models of automobiles [9]. A weakness of these techniques is that they can only produce forms that are a combination of prior forms i.e., they are interpolative rather than creative [10].

## **2 Automobile styling based on designers' perceptions and morphing**

According to Tovey, the design of motor cars is almost always evolutionary, where designs do not change radically from one model to the next. The basic elements and components, such as wheels, seating position, engine, etc. remain the same [11]. This has allowed the industry to structure its design to manufacturing processes in a very compartmentalized and sequential way, with a number of specialist inputs being involved. More particularly than in any other product area the industrial design activities have also become highly specialized and focused towards determining the appearance and identity of the product. Until quite recently they were generally referred to as automobile stylists.

According to Kimura (1997), in the near future, innovation may happen through styling based on technological trends, inevitably changing product development processes. For automobile styling the following very clear trends of evolution can be identified [12]:

- (a) Total time period required for design has been steadily reduced. However, the most important difference between past and future is not the reduction of time, but the change of the relative importance of each design process phase. In the past, design detailing and final drawing took a major portion of the design work, whereas, in future, planning and concept design will take most of the time, and especially drawing work can be eliminated due to the complete shape modeling in detailed design phase.
- (b) The usage of Computer Aided Design (CAD) systems will be expanded up to the planning phase, and the total design process will be integrated by CAD-based digital models. Nowadays, much repeated data input is necessary, because each phase is supported by different CAD systems.
- (c) Manufacturing consideration will be initiated from the phase of planning. This activity will be very effective for reducing the total time required for quality of body engineering.

According to Edson, automotive designers, in order to have control of the complex sculptural forms, imagine shapes in a mental space while they conceive them [13]. This simulation by visualization of the imagined real space establishes the field in which the conceptualization takes place. It can be said that the mental process goes back and forth in this space, as if the designer was trying to grasp it mentally as well as physically. It also appears that the space itself seems to undergo a distortion, a blur, as if ideas oscillated through themselves.

In embodying the concept of connecting the relationship between products and their images, several methods such as fuzzy theory, multidimensional scaling (MDS) methods were proposed [14, 15]. Although they can be used to design a product with a given image, they cannot yet be used to predict the image of a new shape generated with original shapes.

Form can be generated by analyzing human responses to shapes and thereby defining the transformations between descriptive words and shape. For

example, assessment of what a product is (semantic interpretation), may influence judgments on the elegance of a design (aesthetics impression) and the social values it may connote (symbolic association) [16]. In a sense, words are the ultimate high-level form operators and constitute a common language for all of the participants of the conceptual design phase: designers, engineers, marketers and test consumers. Unfortunately, the compactness of verbal expression also leads to ambiguity.

### 3 Automobile Representation

As stated in the previous section, there has been a lack of discussion related to automobile representation. No clear explanation concerning intentions emerges from literature studies. However aesthetics, semantic and symbolic aspects as well as the uses of sketches as means of representation are important to be defined. According to Crilly [16], designers' tacit understanding of perception and visual composition often guide their intuitive judgements [17, 18]. In car design, the designers use their skills, training and experience to design automobiles that induce a positive aesthetic impression. Indeed, there are those who feel and perceive that intuitive creativity is all that is required for the production of visually attractive products contrary to a scientific approach, which is not relevant for understanding the problem. This view may be reinforced by the discovery that very few of the scientific studies have led to generalisations which are useful for students or practitioners of design [19]. However, designers and consumers often interpret products differently and express different aesthetics preferences [20]. Thus, although styling is the 'artistic' part of product design, it must still be directed towards opportunities and held within constraints [21]. As such, Coates suggests that correlating consumer perceptions with product features may align product designs better with consumers' aesthetic preferences [22].

In the automobile industry, a semantic approach to design emphasises on the opportunity for consumers to interpret a product's utility and associated qualities. Krippendorff [23] thus proposes that "design is making sense (of things)" and that designers should facilitate the user in correctly interpreting the product. To assist designers in this mission, Butter [24] has suggested a sequence of activities that integrate semantic considerations into the design process.

The key stages of the process are: firstly, to establish the overall semantic character that the product should communicate; secondly, to list the desired attributes which should be expressed; and thirdly, to search for tangible manifestations capable of projecting the desired attributes through the use of shape, material, texture and colour [24]. Not only has knowledge of semantic principles been shown to improve the clarity of students' designs [25, 26], but commercially successful products have also been produced with explicit consideration given to their semantic character [27]. For designing a new product, Opperud states that "it is the designer's job is to decode the common values and opinions that exist in a culture, and reproduce them into forms that embody the appropriate symbolic meaning [28]."

Once the form is defined, curves characterizing and structuring the car embodiment are considered most important. In the profile view, these curves are for example the roof line; the waist (or belt) line and the front and rear panel overhangs. By definition, the waist line is the curve dividing the side windows and the body side, while the overhang is the distance between the front/rear part of the car and the centre of the wheel. In practice, rather than the waist line, a curve (the accent line) just below is considered for the character evaluation. Actually, the accent line may be a light line; a curve only perceived when light is reflected. In fact, it is a common habit for stylists to work with all of these characters.

### 4 Research Objective

The purpose of this research is to study the designers' perceptions of characteristics of form treatment in automobile styling. Research objectives are three-fold:

1. To find out how recognition is formed by visual elements of the car.
2. To determine what form characteristics are important for creating expressive properties of product form.
3. To find out what words are generally used by designers to describe expressions of car designs, specifically based on a word list and images of cars.

### 5 Research Method

According to Patton [29] the purpose, use, credibility and available resources also dictated the size of sample. Representatives rather than scale were primary





Figure 1. Five Views of a Sedan Car: Proton Waja

concerns as indicated by Oppenheim [30] and Erdos [31]. The structure of questionnaire depends on different aspects such as purpose, respondent group [31]. In this research a survey questionnaire was used to better understand designers' perceptions of characteristics of form design in automobile styling. Type of respondents and survey questions will be further elaborated in this chapter.

### 5.1 Type of Respondents

In this study, 46 practicing vehicle designers, vehicle design students and educators participated by responding to a survey questionnaire. A majority of the practicing designers were from Malaysian vehicle manufacturers, such as Proton, Perodua, NAZA Automotive Manufacturing, Modenas, Proreka (M) Sdn. Bhd., and Norwegian company Inocean AS. Students and educators were from United Kingdom (Coventry University, Royal college of Art), Sweden (Umeå University), Norway (Norwegian University of Science and Technology) and Malaysia (Universiti Teknologi MARA). Several studies have classified respondents based on their expertise. For example Popovic has categorized expertise of design students engaged in a five year program according to three levels: Novice, Intermediate and Expert [33]. Bouchard considered experts professionals currently working in the branch, intermediate experts the students having acquired a concrete skill in car styling by the participation in several industrial projects, and the novice students those who have not yet acquired concrete experience in the field [34]. In this study, respondents were classified in four categories according to their level of experience and occupation (Table 1):

- a. Novice: student, educator or practitioner with less than 5 years working experience in industry.
- b. Intermediate: educator or practitioner with 5 to 10 years working experience in industry.
- c. Senior: educator or practitioner 8/10 to 15/18 years working experience in industry.
- d. Expert: educator or practitioner with more than 18 years working experience in industry.

		Experience in design				Total
		Novice (Less than 5 yrs)	Inter- mediate (5 - 10 yrs)	Senior (8/10 - 15/18 yrs)	Expert (above 18 yrs)	
Occupation	Student	14	0	0	0	14
	Academic	0	0	0	1	1
	Practitioner	21	1	7	1	30
	Others	0	1	0	0	1
Total		35	2	7	2	46

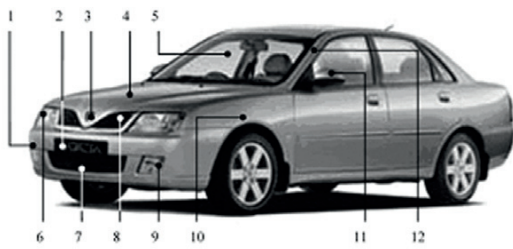
Table 1. Level of design experience and number of occupation among the respondents

### 5.2 Survey Method

A standard questionnaire of nine questions were presented and grouped into 3 sections, each section comprising of 3 questions. The questionnaire employed a combination of qualitative and quantitative questions, including categorical multi choice questions, open ended questions and a combination of these, as well as Visual Analogue Scales (VAS). If required, respondents were guided through the questionnaire by the interviewer, who clarified the meaning if any uncertainties occurred. The first section aims to study the common characteristics of a car [35]. Because of practical and popular reasons, the image of a Malaysian Sedan car model of Proton Waja has been selected. According to the Automobile Magazine (2009, April 27), Sedan reviews, sedan cars are still the majority worldwide [36].

In the first question, respondents were asked to indicate which view they consider as most important for car recognition (see Figure 1). In the second question respondents were asked to indicate, according to Figures 2A and 2B, which components were considered to be essential in determining the recognition of a car.

With reference to question three, it has been found that many researchers studying form totality, whether art-based or science-based, have adopted the properties of Point, Line, Plane or surface and Volume as basic form elements [6, 37, 38]. Respondents were encouraged to rate the importance of each form element according to its ability to convey a certain perception. In order



**Figure 2A.** Selected Car Components on 3 quarter front view. Note: (1) Front bumper; (2) Front plate number; (3) Emblem; (4) Hood panel; (5) Windscreen; (6) Head lamp; (7) Air intake; (8) Radiator grill; (9) Fog lamp; (10) Fender; (11) Side mirror; (12) A-pillar.



**Figure 2B.** Selected Car Components on 3 quarter rear view. Note: (13) Tail lamp; (14) Trunk lid; (15) Rear emblem; (16) 3rd brake light; (17) C-pillar; (18) B-pillar; (19) Rear bumper; (20) Exhaust; (21) Rear plate number; (22) Body trim; (23) Side signal; and (24) Wheel.

to make the respondents understand the terminology, a geometrical explanation for each form element was provided.

In section 2 of the questionnaire, emphasis was placed on how features, as a tool to verbalize the perception of a car, are used in the understanding of form principles and form elements. In question six, a Semantic Differential Style has been used. We explored the words based on adjectives. In addition, the words are not necessarily 'contradictive' in meaning. The questions supporting this section were formulated as follows:

Question 4: How do you rate the following principles of form in association to the perception of a car, according to a five point scale (not important – extremely important)?

Question 5: How do you rate expressive value of specific form features in design, supported by form elements, such as curve, line, and surface?

Question 6: To what extent do you disagree or agree that the following bi-polar adjectives can be used in the design of the car and its form elements?

In section 3, Question 7 respondents were asked to indicate a perception when presented with the front, side and rear view of 36 images of different types of cars, sub-divided into 12 front view, 12 side view and 12 rear view images. The cars were heuristically selected by the researchers.

## 6 Data Analysis

Data was statistically analyzed directly as well as indirectly using a Statistical Package for the Social Sciences (SPSS) version 15 for Windows. Frequency distribution tests were conducted for the direct analysis of each individual question. In addition Chi-Square tests were run for section 3. For the indirect analysis, mainly

correlation tests based on bi-variate statistics were conducted to evaluate the relationship among the five views, among selected car components, between form elements and perceptions based on pre-selected car models, between form features and bi-polar adjectives, between car components and form features, and between car components and bi-polar adjectives (Table 2). In order to test the reliability of this questionnaire, the reliability statistics model of Cronbach's Alpha have been used [39]. Cronbach's Alpha is a reliability coefficient that indicates how well the internal consistencies of items in a set are positively correlated to one another. It shows that the analysis results for this questionnaire are high at 0.862.

Base software	Test	Descriptions
Descriptive statistics	Frequency distributions	A frequency distribution is a display of the frequency of occurrence of each score value.
Bivariate statistics	Correlations	A Pearson product-moment correlation coefficient describes the strength and direction of a linear relationship between two continuous variables.
	Chi-Square test (non-parametric test)	The best-known situations in which the chi-square distributions are used are the common chi-square tests for goodness of fit of an observed distribution to a theoretical one, and of the independence of two criteria of classification of qualitative data.

Table 2. Statistical Test conducted for this research

## 6.1 Findings

The first section shows that 63% of the respondents consider the three quarter front view as providing the strongest recognition of a car (i.e., brand, type of car, category, properties, country of origin, or other characteristics). However out of the selected 24 components for the car, five components were considered essential in determining the car recognition.

These components are Front emblem (50%), Head lamp (80%), Radiator grill (80%), Tail lamp (89%), and Rear bumper (58%).

Form Elements	Important	Very important	Extremely important
Port	43.7	13.0	6.5
Line	8.7	34.8	54.3
Plane or Surface	26.1	37.0	32.6
Volume	26.1	19.6	52.2

Table 3. Frequency distribution of importance ratings of Form Elements

When considering the ability of each form element to convey a certain perceptions. It shows that all form elements were rated between “important” to “extremely important” (see Table 3). However the relative percentage of frequency distributions indicate that Line (97.8%) and Volume (97.9%) followed by Plane/surface (95.7%) are most important in determining the perceptions of a car.

Many automotive designers use form elements and the manipulation of principles of form when developing and communicating the main form of the vehicle or its components [40, 5].

Principles of Form	Important	Very important	Extremely important
Unity and variety	37.0	41.3	10.9
Balance	10.9	45.7	41.3
Emphasis v. subordination	52.2	30.4	13.0
Directional forces	30.4	41.3	21.7
Contrast	39.1	30.4	10.9
Repetition and rhythm	34.8	37.0	17.4
Scale and proportion	4.3	21.7	73.9

Table 4. Percentage of Principles of Form rated by designers

In section 2, it was found that the use of form elements needs to be added with the understanding of the principles of form. Based on a rating between “important” to “extremely important” (see Table 4), a percentage of frequency distributions indicate that balance, directional forces, and scale and proportion are the most important principles of form of a car. This finding is important as it provides evidence to principles that car designers colloquially mention as essential. It is also interesting to note that all principles rate very high in accumulated score; however it is not unexpected, because all form principles used by designers would probably be rated as at least “important,” or otherwise they would not be used by designers.

Form Features	Important	Very important	Extremely important
Accelerate (curve, line, surface)	26.1	37.0	34.8
Arc	34.8	34.8	17.4
Bevel	41.3	28.3	17.4
Bone	41.3	34.8	17.4
Chamfer	34.8	39.1	10.9
Crease	43.5	37.0	13.0
Cut-line	37.0	34.8	17.4
Edge	43.5	34.8	13.0
Fillet	34.8	41.3	10.9
Flush	37.0	30.4	23.9
Radius	32.6	26.1	32.6
Taut	39.1	30.4	15.2

Table 5. Percentage of Selected Form Features rated by designers

To assess the expressive value of “form features”, twenty eight form descriptive terms were selected and adopted from Saunders [41]. Of course, the types of form features which are more frequently or consistently used depends on the type of design format/style (given by brand identity, expression, form language, etc) employed in a particular car design. The ratings given only provide an understanding of perceptions of car designers regarding general (across typical car designs on the market) or possibly individual (given by the style of each designer) tendencies for the use of certain form features in car design. All form features were considered “important” to “extremely important” (see Table 5). However a selected number of form features show a high cumulative percentage and above 10% score on “extremely important.” It seems that the form feature “accelerate” is highly rated compared to the others, as it denotes a behavior of compositions of form features, rather than being a form features itself.

To find out whether bi-polar adjectives can be used in the design of the car and its form elements, forty eight of them were heuristically selected or derived from other sources such as Semantic Differential [42, 43]. The findings indicate that 38 bi-polar adjectives are commonly being used by car designers when expressing their feeling about the car. Out of these 38, the following 15 bi-polar adjectives with accumulative score above 80% or above 30% score for “strongly agree” are being favored (see Table 6). It is interesting to note that dynamic – static, feminine – masculine, and aggressive – submissive are the strongest rating bi-polar adjectives, which seem to correspond to common perceptions of modern cars. The designers’ response to this question may be interpreted as indicating that a continuum of perceptions of form characteristics, as described by the

extreme bi-polar endpoints given by the adjectives, are commonly used in car design.

Three bi-polar adjectives were considered neutral among the respondents. They are charming – displeasing, cheerful – sad, and intelligent – stupid.

However, the following adjectives have been rejected by the respondents: cheeky – backward, contempt – not contempt, disgusted – not disgusted, gorgeous – plain, happy – unhappy, pleasant – annoyed, sleepy – alert, stupid – smart, truthful – exaggerated and worried – assured.

Bi-polar Adjectives	Agree	Strongly agree
Aggressive – submissive	37.0	52.2
Avant-garde – conservative	41.3	39.1
Contemporary – traditional	43.5	37.0
Dynamic – static	39.1	56.5
Elegant – not elegant	39.1	45.7
Excited – bored	52.2	28.3
Exclusive – inclusive	34.8	45.7
Feminine – masculine	39.1	56.5
Futuristic – nostalgic	39.1	47.8
Heavy – light	54.3	32.6
Innovative – imitative	50.0	37.0
Simple – complex	58.7	34.8
Streamlined – rugged	34.8	50.0
Strong – weak	52.2	34.8
Soft – hard	43.5	41.3

Table 6. Percentage of Set of Bi-polar Adjectives for car perceptions rated between “strongly agree” to “agree”

With regard to section 3, where adjectives, representing designer perceptions, were correlated to specific car models and their respective images from the front, side and rear view, it can be concluded that all 36 images evoke certain perceptions. For all three views a high standard deviation and broad range between minimum and maximum is noticed, which means that the perceptions of each designer are highly variable. In order to study the perception of individual designer with an image of the car, we have made an open-ended question with provided images of the car randomly. Since the answers by the designers’ are varied, the best test for the analysis is using the Chi-square test, the test uses to analyze abnormal data based on individual interpretations or non-consistencies of individual answer. The verbs expressed by the respondents were analyzed using descriptive statistics based on percentage of frequency distributions and bi-variate statistics based on Chi-Square test for goodness of fit (non-parametric techniques). An example of the test results is shown in Table 7.

To verify whether the 3 quarter front view is the only significant view for the recognition of a car, a correlation was conducted among all views. Based on a negative 2-tailed correlation (Pearson -0.419(\*\*)) it can be specifically noted that there is no relationship at all between the three quarter front view and front view in determining the recognition of a car, which means the designer did not reflect or respond on that view. We have assumed that the recognition would refer to one brand (recognition as an identity mode is based on the iconic sign, i.e. recognition through similarity/likeness to something seen before), while the other view would to some other brand, or not to any brand at all. It may also refer to identification of (other) characteristics of cars. It seems reasonable to assume that recognition of type (of product), i.e. categorization in terms of e.g. type of car such as sedan, family, or micro car, would not be dependent on the view, as car designers are familiar with design characteristics for different types of cars.










Image	Model	N	Mean	Std. Dev.	Min	Max
	Volkswagen New Beetle	38	71.29	43.724	5	157
	Citroën DS	41	69.80	54.292	3	160
	BMW 3 Series	39	80.82	51.573	3	156
	Smart Fortwo	39	64.23	33.736	24	111
	Mini Cooper S	40	79.58	36.309	4	122
	Mitsubishi Galant Fortis	41	77.15	41.314	2	120
	Volvo S80	40	99.75	37.955	1	142
	Audi TT	37	85.00	44.487	2	125
	Volkswagen New Beetle	39	65.38	42.874	6	132

Table 7. Example of test results where images of cars in front, side and rear view are assessed on their expressive qualities.

The study revealed that “front emblem”, “head lamp”, “radiator grill”, “tail lamp”, and “rear bumper” are significant components for determining the recognition

of a car. A positive 2-tailed correlation test shows that head lamp, radiator grill and tail lamp have strong relationships in jointly determining the recognition of a car (see Table 8). It should be noted that this result might reflect the general opinion of designers regarding which components are typically important for (brand) recognition. However, it is easy to imagine car design where other form features, such as bone lines or characteristic curves, may be used to create the same references to brand characteristics.

The correlation test between the form elements and the perceptions of the car based on specifically provided images has led to the following findings. Reference to the front view (see Table 9), Chevrolet Camaro and Line are positive 2-tailed correlation (Pearson 0.524(\*\*)) based on the perceptions of aggressive,

		Head lamp	Radiator grill	Tail lamp
Head lamp	Pearson Correlation	1	.171	.356(*)
	Sig. (2-tailed)		.255	.015
	N	46	46	46
Radiator grill	Pearson Correlation	.171	1	.708(**)
	Sig. (2-tailed)	.255		.000
	N	46	46	46
Tail lamp	Pearson Correlation	.356(*)	.708(**)	1
	Sig. (2-tailed)	.015	.000	
	N	46	46	46

\* Correlation is significant at the 0.05 level (2-tailed).  
 \*\* Correlation is significant at the 0.01 level (2-tailed).

Table 8. Correlations among Significant Components

		Point	Line	Plane or surface	Volume
Chevrolet Camaro (Aggressive, confidence, cheerful, futuristic)	Pearson Correlation	.213	.524(**)	.312(*)	-.018
	Sig. (2-tailed)	.193	.001	.050	.910
	N	39	39	40	40
Aston Martin DB9 (Aggressive, confidence, elegant, speed)	Pearson Correlation	-.123	.361(*)	-.014	-.070
	Sig. (2-tailed)	.475	.030	.935	.680
	N	36	36	37	37
Ford Cougar (Aggressive, dynamic, happy, odd, ordinary)	Pearson Correlation	.133	.405(*)	-.106	-.054
	Sig. (2-tailed)	.441	.014	.531	.753
	N	36	36	37	37
Mitsubishi Lancer (Aggressive, anger, confidence, brave)	Pearson Correlation	-	.261	-.067	-.125
	Sig. (2-tailed)	.006	.113	.683	.448
	N	38	38	39	39

\* Correlation is significant at the 0.05 level (2-tailed).  
 \*\* Correlation is significant at the 0.01 level (2-tailed).

Table 9. Correlations between the Form Elements and the Expressions of Car Front View

confidence, cheerful, and futuristic, whereas the same car and Plane or Surface indicate a positive 2-tailed correlation (Pearson 0.312(\*) based on the perceptions of aggressive, confidence, cheerful, and futuristic. Aston Martin DB9 and Line are positive 2-tailed correlated (Pearson 0.361(\*) based the perceptions of aggressive, confidence, elegant, speed; whereas Ford Cougar and Line show a positive 2-tailed correlation (Pearson 0.405(\*) based on the perceptions of aggressive, dynamic, happy, odd, and ordinary.

Reference to the side view (see Table 10), Lotus Elise and Line are positive 2-tailed correlated (Pearson 0.460(\*\*)) based on the perceptions of dynamic, sporty, fast, and streamlined; Jaguar XK Coupe and Line are positive 2-tailed correlated (Pearson 0.405(\*\*)) based on the perceptions of sleek, aerodynamic, classy, contemporary, streamlined. Toyota Yaris and Line are positive 2-tailed correlated (Pearson 0.398(\*) based on the perceptions of cute, cheeky, compact, contemporary, smart. This means that "Lotus Elise and Line," "Jaguar XK coupe and Line," and "Toyota Yaris" show strong relationships between the form elements and perceptions based on specific car models.

A negative 2-tailed correlation has been found between Jaguar S-type and Point based on the perceptions of elegant, exclusive, formal, traditional; between Mercedes E-class Wagon and Volume based on the perceptions of elegant, bulky, exclusive, family, and long; between BMW I Series and Volume, and between Smart Fortwo and Point based on the perceptions of dynamic, aerodynamic, and smart. This means that "Jaguar S-type and Point," "Mercedes E-class Wagon and Volume," "BMW I Series and Volume," and "Smart Fortwo and Point" show no relationships between the form elements and perceptions based on specific car models.

For the Rear view (see Table 11), only a positive 2-tailed correlation (Pearson 0.327(\*) can be found between Lotus Elise and Line based on the perceptions of dynamic, sporty, fast, and streamlined, indicating a strong relationship between the form elements and perceptions. This means that reference to the front, side and rear views strong relationships can be found between certain form elements and car perceptions based on selected car images.

When analyzing the relationship between 28 form features and all 48 bi-polar adjectives, a positive 2-tailed correlation can be found between 11 bi-polar adjectives and 17 form features. The pairing between the respective bi-polar adjectives and form features is shown in Table 12.

Correlation tests were conducted between all 24 car components and 28 form features (see Table 13). A positive 2-tailed correlation is found for “Rear bumper and Blister” and “Head lamp and Radius”, indicating strong relationships between these components and form features. A negative 2-tailed correlation is found for “Front emblem and Coke-bottle/wasp-waist”, “Front emblem and Cut-line”, “Tail lamp and hollow”, and “Front emblem and Taut”, indicating that there is no relationship at all between these form features and car components.

Chen et al. have applied Conceptmorph and Conjoint Analysis to explore a large number of shapes by modifying the entire car or its components on spectra of bi-polar adjectives [44]. However, components and bi-polar adjectives were randomly selected. In this study, an attempt to correlate 24 car components with the 48 bi-polar adjectives has only surfaced a positive 2-tailed correlation between “Front emblem and Intelligent-stupid” (Pearson 0.306\*). However, “Intelligent-stupid” is not part of the list of popular bi-polar adjectives.

## 7 Discussion

It is a common practice in car design as well as other product categories to “borrow” characteristic features from already existing products, in order to emphasize design heritage, product and brand identity, and recognition, thus providing a visually characteristic form and a consistent design format [5]. These tendencies have evoked the interest of the researchers to conduct a more fundamental study on how designer perceptions can be used as a basis for automobile styling by correlating selected adjectives with form elements and car components.

According to Tovey, Porter, and Newman who undertook an analysis of the content of a number of automotive sketches with the intention of categorizing the visual components, and determining which are the most important in communicating 3D form,

		Point	Line	Plane or surface	Volume
Lotus Elise (Dynamic, sporty, fast, streamlined)	Pearson Correlation	,080	,460(***)	,135	-,256
	Sig. (2-tailed)	,637	,004	,419	,121
	N	37	37	38	38
BMW 1 Series (Dynamic, Aerodynamic, smart)	Pearson Correlation	-,061	-,086	-,075	-,382(*)
	Sig. (2-tailed)	,717	,606	,651	,016
	N	38	38	39	39
Jaguar XK coupe (Sleek, aerodynamic, classy, contemporary, streamlined)	Pearson Correlation	,099	,405(***)	,154	-,027
	Sig. (2-tailed)	,542	,010	,336	,868
	N	40	40	41	41
Smart Fortwo (Cute, compact, fun, static, intelligent)	Pearson Correlation	-	,137	-,027	-,196
	Sig. (2-tailed)	,039	,411	,871	,232
	N	38	38	39	39
Toyota Yaris (Cute, cheeky, compact, contemporary, smart)	Pearson Correlation	,009	,398(*)	,238	-,228
	Sig. (2-tailed)	,955	,011	,133	,152
	N	40	40	41	41
Jaguar S-type (Elegant, exclusive, formal, traditional)	Pearson Correlation	-	,029	-,036	-,289
	Sig. (2-tailed)	,004	,859	,825	,067
	N	40	40	41	41
Mercedes E-class Wagon (Elegant, bulky, exclusive, family, long)	Pearson Correlation	-,188	,087	-,034	-,399(**)
	Sig. (2-tailed)	,238	,590	,833	,009
	N	41	41	42	42

\* Correlation is significant at the 0.05 level (2-tailed).

\*\* Correlation is significant at the 0.01 level (2-tailed).

Table 10. Correlations between the Form Elements and the Expressions of Car Side View

		Point	Line	Plane or surface	Volume
Lotus Elise (Dynamic, sporty, fast, streamlined)	Pearson Correlation	-,092	,327(*)	,192	,011
	Sig. (2-tailed)	,577	,042	,236	,945
	N	39	39	40	40

\* Correlation is significant at the 0.05 level (2-tailed).

Table 11. Correlations between the Form Elements and the Expressions of Car Rear View

Bi-polar adjectives	Form features
Anger - calm	Cut-line (.323*)
Charming - displeasing	Coning (.328*), Radius (.296*)
Cheeky - backward	Bulge (.339*)
Cheerful - sad	Arc (.309*), Hollow (.347*)
Comfortable - uncomfortable	Arc (.424**), Extrusion (.362*), Hollow (.393**), Lathe (.314*), Pooches (.328*)
Consistent - inconsistent	Concave (.309*)
Contemporary - traditional	Concave (.330*)
Contempt - not contempt	Blister (.386*), Concave (.333*), Dimple (.455**), Hollow (.397**)
Disgust - not disgust	Coke-bottle/wasp-waist (.342*)
Excited - bored	Arc (.359*)
Fear - brave	Bulge (.300*), Extrusion (.293*), Hollow (.419**), Lathe (.312*), Sheer (.390**)

\* Correlation is significant at the 0.05 level (2-tailed).

\*\* Correlation is significant at the 0.01 level (2-tailed).

Table 12. Positive Correlations between Form Features and Bi-polar Adjectives

		Front emblem	Head lamp	Radiator grill	Tail lamp	Rear bumper
Blister	Pearson Correlation	.075	.175	-.065	.037	.334(*)
	Sig. (2-tailed)	.630	.237	.673	.814	.026
	N	44	44	44	44	44
Coke-bottle/wasp-waist	Pearson Correlation	-.318(*)	.071	.009	-.063	.039
	Sig. (2-tailed)	.031	.639	.951	.677	.799
	N	46	46	46	46	46
Cut-line	Pearson Correlation	-.371(*)	-.279	.131	.044	-.112
	Sig. (2-tailed)	.012	.064	.391	.776	.465
	N	45	45	45	45	45
Hollow	Pearson Correlation	.027	.093	-.247	-.367(*)	-.052
	Sig. (2-tailed)	.839	.539	.098	.012	.731
	N	46	46	46	46	46
Radius	Pearson Correlation	-.135	.333(*)	-.153	-.136	.203
	Sig. (2-tailed)	.371	.024	.309	.367	.176
	N	46	46	46	46	46
Taut	Pearson Correlation	-.379(*)	.269	.024	.035	-.109
	Sig. (2-tailed)	.010	.074	.873	.822	.475
	N	45	45	45	45	45

\* Correlation is significant at the 0.05 level (2-tailed).

Table 13. Correlations between Car Components and Form Features

components, such as headlamps, tires, mirror, etc. are essential in giving meaning and identity to the overall design [45].

In this study, Front emblem, Head lamp, Radiator grill, Tail lamp, and Rear bumper have been found to be significant components for determining the recognition of a car, both as an individual component and coherently.

Tovey and Porter described that "emotional characteristics" such as friendly and aggressive, are most easily described by the 'face' or front view of the vehicle [46]. However, in this study it is found that the three-quarter front view provides the strongest recognition of a car. We believe our comparison is possible to make, as Tovey discusses emotional response and a tendency for the creation of such perceptions in the front view of the car, while we discuss recognition (which we interpret as identification of brand), which is a characteristically different experiential aspect [47].

In terms of form elements, the relative percentage of total frequency distributions indicates that Volume and Line, followed by Plane/Surface are considered most important in determining the perception of a car. With respect to the rating of these elements as "extremely important", the frequency distributions of Line (54.3%) and Volume (52.2%) followed by Plane or Surface (32.6%) are not unexpected. Because points are used only to a limited extent as an explicit design element in car design, it is as expected considered less essential (6.5% "extremely important"). Balance, directional

forces, and scale and proportion are being considered as the most important form principles of a car.

According to Table 6, 15 out of the 38 sets of bi-polar adjectives presented to designers were considered to be expressed in car design. However, alternative expressions, such as bi-polar scales, that describe designers' perceptions of cars need to be further investigated. Furthermore, the use of word pairs does not tell us anything specific about what types of perceptions designers actually have, or whether they perceive the word pairs used as being opposites.

However, we found that there are two styles of structured questionnaires where words pairs (bi-polar adjectives) are employed on a Semantic Differential scale. The first style is a direct contradiction of word pairs. This contradiction means that the word selected has an "explicit" representation of the meaning like "beautiful" versus "ugly". For example, Hsiao and Liu uses the image of a specific product by adjectival images words like traditional-modern, complex-simple, cheap-expensive, cold-warm, soft-hard, etc [48]. The second style is an indirect contradiction of word pairs. This contradiction means that the word selected has an "implicit" representation of the meaning such as "beautiful" versus "not beautiful". For example, Ishihara, Ishihara and Nagamachi uses the list of adjectives randomly like pretty-not pretty, intellectual-not intellectual, elegant-not elegant, derived from sources such as magazines, mail-order catalogs, recordings of conversation, etc [49].

A clear relationship can be found between a wide range of bi-polar adjectives and form features. As form features represent certain form elements, such as lines, surfaces and shapes, these may be developed according related bi-polar adjectives. Complementary, with reference to the front, side and rear views, strong relationships can be found between certain form elements and car perceptions based on selected car images. Popular perceptions, with reference to the front view, are aggressive, confidence, cheerful, futuristic, elegant, speed, dynamic, happy, odd, and ordinary. Popular perceptions based on the side view are dynamic, sporty, fast, streamlined, aerodynamic, sleek, classy, contemporary, cute, cheeky, compact, and smart. Frequent perceptions for the car rear view are dynamic, sporty, fast, and streamlined. A comparison across the three views shows that the adjectives aggressive, cute, and dynamic are important.

## 8 Conclusion and Further Research

This study has shown that there are valid correlations between selected designers' perceptions and form elements/car components of an automobile. This justifies the search on how these selected designers' perceptions can be used as a foundation for automobile styling.

Further research will test the applicability of designers' perceptions in hands-on automobile sketching. In terms of methods, video observations will be conducted to better understand how designers visualize automobiles during sketching as well as its components along selected bi-polar spectra, represented with a car image on either extreme. The visualization process will be supported by the recognition of visual characteristics, elements and components of a car, expressed through words generally used by designers.

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**Paper 5**      Understanding styling activity of automotive designers: A study of manual interpolative morphing through freehand sketching.

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## **UNDERSTANDING STYLING ACTIVITY OF AUTOMOTIVE DESIGNERS: A STUDY OF MANUAL INTERPOLATIVE MORPHING THROUGH FREEHAND SKETCHING**

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### **ABSTRACT**

Automated morphing techniques have been proposed as a design support tool to generate novel shapes which lie between two or more polar reference images. The purpose of these techniques, employed in automated morphing systems (AMS), is to assist designers and design teams in the task of generating new shapes and finding novel form concepts. However, the usefulness of such systems for design practice may be questioned, as they significantly differ from designers' sketching processes during morphing. In this paper, we investigate the sketching processes of automotive designers in order to understand their processes of manual interpolative morphing employing freehand sketching. The objective was to understand and describe the result of their morphing processes, and relate the findings to the output of typical AMS, in order to evaluate the usefulness of AMS for design purposes. The aim was to understand how designers morph elements of product form, what types of elements are morphed, and how these elements are transformed through morphing. Results suggest that there are profound differences between manual and automated morphing. Specifically, these relate to selectivity, consistency, and completeness of morphing operations. While designers choose and transform shape based on subjective and purposeful intent, AMS lack these characteristics. These differences influence the outcome of morphing processes to a fundamental degree. Designers and design teams will be supported by these findings when considering the employment of AMS in design work. The research describes the characteristics and clarifies the potential contribution of AMS in styling activities, thus assisting the evaluation of AMS in relation to traditional, manual sketching approaches.

*Keywords: automotive design, form composition, morphing techniques, perception, styling process*

### **1 INTRODUCTION**

Designers widely employ manual sketching as a tool to explore and understand new ideas and concepts for form and function in product design [1]. During sketching, the design idea is represented in the translation of the idea from abstract to concrete. According to Tovey, Porter and Newman [1], the actual process of creating design idea is usually envisaged as going on in the mind's eye and drawings as attempts to reproduce the designer's mental images.

Schön and Wiggins [2] have investigated kinds of seeing and their relationship with the design activity. They regard designing as a conversation with materials conducted in the medium of drawing, and crucially dependent on seeing. It is characterized as a reflective conversation with materials whose basic structure-seeing-moving-seeing- is an interaction of designing and discovery. Designers draw on paper, observing the evolving product of their work, employing different kinds of seeing (visual apprehensions, literal seeing), and, as this is done, discoveries are made. Features and relations are identified which cumulatively generate a fuller understanding, or 'feel for' the configuration with which designer's is working. They conclude that this involves giving attention to a process that computers are presently unable to produce.

Two types of sketching that often occur in the design process are the free, exploratory search for new design ideas, and the more focused refinement of an overall theme once a main motif is established. As noted by Akner-Koler, a divergent approach, searching for more types of solutions, is generally employed early in design processes, while a narrower but deeper exploration of variance is used once

a theme has been selected [3]. These two purposes of sketching may be compared to Goel's [4] categorization of sketching relating to, respectively, lateral transformation, where more divergence is introduced, and vertical transformation, where more convergence is introduced. Goel argues that the characteristics of the design process stem from the ill-defined nature of design problems in contrast to the well-defined problems. Secondly, he argues that sketching constitutes a particular of symbol system, which is characterized by syntactic and semantic denseness and by ambiguity, and it is the aspects of sketching which allow lateral transformation to occur. In his analysis, transformation may be either lateral or vertical, while reinterpretations occur when the meaning associated with a drawing in one episode is subsequently changed. Goel concludes that sketching is associated with preliminary design because it is a symbol system that is dense and ambiguous and consequently facilitates the lateral transformations that are an essential aspect of this phase of the design process. These divergent and convergent approaches of sketching play an important role in designers' processes of exploring the possible solution space in design work. According to Goel [4], the inherent characteristics of designers' processes of thinking and sketching – being vague, fluid, ambiguous, and amorphous – thus render them beyond the capacity of currently computational systems.

Automated morphing systems (AMS) generate form variation based on metamorphosis of form structures. It is a quantified structure strategy and it can be based on the variation of arrangement – number and dimension [5]. AMS may be categorized into two types; digital image warping techniques, and design interpolation. Digital image warping techniques employ geometrical transformation of digital images [6]. A geometrical transformation is an operation that redefines the spatial relationship between points in an image. A warp may range from something as simple as translation, scale, or rotation, to something as elaborate as a convoluted transformation [6].

Several approaches have been used for geometric transformation through interpolation (see e.g., [7, 8, 9]). These employ a number of algorithms which have been developed for image morphing (see [6]), such as, e.g., linear and polynomial interpolation, and cubic splines with natural or periodic boundaries. Wolberg [10] presents three approaches work on morphing algorithms before the development of morphing, 1) Cross-dissolve; 2) Mesh warping; and 3) Multilevel free-form deformation (MFFD) based morphing. An example of MFFD-based morphing is given in Figure 1.



Figure 1. Multilevel free-form deformation based morphing (Source: Wolberg [6])

A pioneering work along the direction of design interpolation is the research on shape averaging [11]. Shape averaging produces a series of novel shapes between two polar base shapes. It is hypothesized that the average results are useful for predicting trends in form, or for extracting stereotypes from a group of related shapes. The technique can be used to create new forms by blending general features of existing unrelated shapes. The algorithms of shape averaging enable the extraction of mean, median and mode forms from the average shape (see [11]). Figure 2 shows the blending results between car shape and teardrop shape at different weighted averaging ratios.



Figure 2. Weighted averaging shapes from a car and the teardrop shape under ratios of (a) 70/30, (b) 50/50, and (c) 30/70 (Source: Chen and Parent [11])

Designers approach to form generation is, thus, principally radically different to that of AMS. Instead of generating shapes through continuous shape merging, designers construct shape through the establishment of primary elements, which are modified and developed through iteration. In this process, the form structure, also known as gestalt, of the artifact is constructed. A product gestalt is the arrangement of parts which constitute and function as a whole product, but which is more than the sum of its parts [12]. In a product gestalt, the compositional structure may be seen as consisting of form elements on various hierarchical form structure levels, which are visually interrelated in a complex manner within and between levels (Warell [13]). Warell [13] suggests an analysis technique based on visual decomposition of these structural levels (superior, intermediate, and detail levels), which facilitates the definition of purpose, type, and visual function of form elements in a product gestalt. Critically, each element may thus be recognized, articulated and understood, in terms of how it contributes to the overall gestalt. Thus, the syntactic and semantic contribution of specific form elements may be articulated.

## **2 RESEARCH OBJECTIVE**

Although much research has been devoted to understanding designers' sketching process (e.g., [1, 14]), no studies have been found which try to describe or understand how human designers morph between two or more polar base images using sketching (or other media or tools). Furthermore, recognition of the inability of computational systems to replicate the vagueness and ambiguity of the human sketching process (e.g., [2, 4]) has contributed to the formulation of the objective of this research: to investigate the characteristics of morphing processes of designers in actual sketching assignments in relation to morphing processes of typical AMS. The aim is to evaluate the usefulness of AMS in relation to manual sketching approaches.

The overall research question of how manual morphing through sketching is different from approaches using automated morphing systems (AMS) thus guided the investigation. Based on findings reported from previous research, three sub questions were developed, according to the following:

RQ1. The ambiguous characteristics of designers' sketching processes will lead to a natural variety in output. We refer to this phenomenon as "consistency". Thus, how do designers assess their own morphing assignments with respect to intended achievement?

RQ2. Designers choose what elements to morph rather than transforming uniformly. We refer to this phenomenon as "selectivity". Thus, we are interested in understanding what types of elements designers morph. What are the characteristics of these elements?

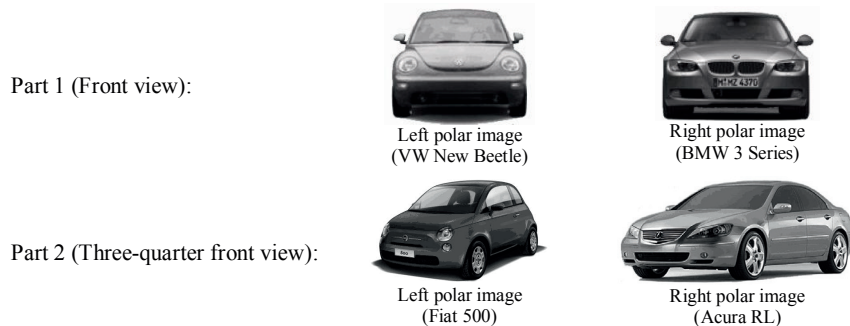
RQ3. Designers may morph only to a partial degree ("completeness"). How, then, are elements morphed by designers with respect to completeness?

## **3 METHOD**

In this research, we explore the operations of form transformations employed by designers during image morphing processes using freehand sketching. We also study the characteristics of these morphing sketches in order to determine how freehand sketches differ from morphing sequences generated by automated systems. Thus, in this work, the use of the bipolar morphing technique is an experimental means to elicit, identify and categorize the types of operations employed by designers during form development. The investigation was based on two studies:

In Study 1, a total of 43 selected automotive designers in the United Kingdom, Norway, Sweden, and Malaysia completed a morphing assignment, which they were subsequently asked to assess in terms of their own morphing performance. Each designer was given the task of performing morphing sequences for five views (front, side, rear, three-quarter front, and three-quarter rear), using manual freehand sketching. In each morphing sequence, designers were asked to produce three sketches, representing the stages of 25%, 50% and 75% transformation, respectively, from the left to the right polar image, thus gradually morphing the left image to the right image in three consecutive steps. Each polar image consisted of a grayscale photograph of a production car currently available on the world market. Subsequently, each designer was given the task to assess their own morphing performance in relation to the assigned task of 25%, 50% and 75% partial morphing target achievement. In the assessment, they were asked to provide a percentage number for each of the sketches in each morphing sequence. For example, a designer who assessed their 25%-target sketch to actually be somewhere between the 25% and 50% target, may have stated 35% for the 25%-target sketch.

Study 2 consisted of three analysis parts. In parts 1 and 2, morphing sequences produced by the designers in Study 1 were analysed by a total of 10 respondents; all final year, master level product design students. Two chosen view sets (front view and three-quarter front view), each represented by five separate morphing sequences of three sketches each, by five different designers, were selected by the authors based on a heuristic quality review. Each respondent was given the task to analyze the selected sets of morphing sequences with respect to similarities and inconsistencies between the sketches and polar images of each respective morphing sequence. In part 1, respondents were asked to assess the front view set, consisting of five front view morphing sequence sketches, with respect to similarities and inconsistencies. In part 2, respondents were asked to assess the three-quarter front view set, consisting of five three-quarter front view morphing sequence sketches, with respect to similarities and inconsistencies. Polar images of the chosen morphing sequences for each part of Study 2 are illustrated in Figure 3. In each part, respondents indicated similarities and inconsistencies using coloured pencils on morphing sequence sketches, printed on A3 paper sheets. Finally, in part 3, the material produced in parts 1 and 2 was heuristically analysed by the authors with respect to form structure levels, according to Warell [13].



*Figure 3. Polar images used in part 1 and part 2, respectively, of Study 2 (brand and model identifiers were not provided to respondents)*

#### 4 FINDINGS

Results from Study 1 show that designers frequently assess their own sketches as being outside the target of the assigned task of 25%, 50% and 75% partial image morphing. As an illustration, Figure 4 presents an analysis of the subjective assessments from 19 of the 43 designers, indicating the range of assessments of sketches for each target transformation for the three-quarter front view. The analysis suggests that the range of assessments for the 25% morphing stage varies between 15% and 30%. For the 50% and 75% morphing stages, the variation is between 40% and 65%, and between 70% and 85%, respectively.

Results from Study 2, part 1, are illustrated in Figures 5 and 6. In Figure 5, inconsistencies as indicated by respondents in the set of five morphing sequences, when compared to the left and right polar base images, are illustrated. Red lines indicate inconsistencies in relation to the right base image, while blue lines indicate inconsistencies in relation to the left base image. For all Figures, numerals denote the number of inconsistencies reported for each element as indicated by respondents.

In Figure 6, similarities as indicated by respondents in the set of five morphing sequences, when compared to the left and right polar base images, are illustrated. Red lines indicate similarities in relation to the right base image, while blue lines indicate similarities in relation to the left base image. Similarly, results from Study 2, part 2, are illustrated in Figures 7 and 8. In Figure 7, respondents have indicated inconsistencies of the set of five morphing sequences as compared to the left and right polar base images. Red lines indicate inconsistencies in relation to the right base image, while blue lines indicate inconsistencies in relation to the left base image.

Finally, in Figure 8, respondents have indicated similarities of the set of five morphing sequences as compared to the left and right polar base images. Red lines indicate similarities in relation to the right base image, while blue lines indicate similarities in relation to the left base image.

In part 3, inconsistencies and similarities as indicated by respondents in parts 1 and 2 of Study 2 were

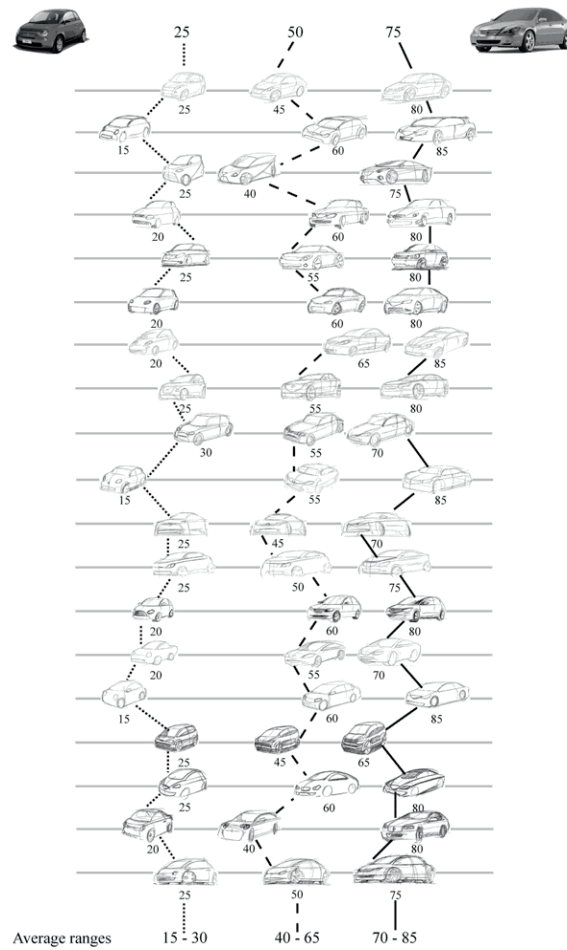


Figure 4. Compilation of designers' assessments of their own morphing achievements for the three-quarter front view, in relation to the morphing target. Average range denotes the lowest and highest assessment of designers' sketches for each morphing target

analysed with respect to form structure levels [13], based on a heuristic evaluation of all indicated elements. In the analysis, form elements indicated by respondents were decomposed and categorized according to three structural levels; Level 1 (superior level), Level 2 (intermediate level), and Level 3 (detail level). Figures 9 and 10 illustrate the analysis of form structure levels for the front view set and the three-quarter front view set, respectively.

## 5 DISCUSSION

In this research, we explored how designers morph between a set of two bipolar images using interpolative freehand sketching. The sketching occurring during interpolative morphing requires the designer to create a continuum of visualizations that differ mainly at the lower form structure levels. This is similar to the transformation occurring during vertical type of sketching, when the designer refines ideas on a detailed level with respect to meaning and content. This vertical sketching occurs, for example, during the stage when the designer moves from the overall to the more detailed stages in automotive concept sketching, and explores variants within a given theme [1, 15].

This research focuses on the characteristics of designers' morphing processes in relation to those of automated morphing systems (AMS). The proposed research questions investigated the morphing



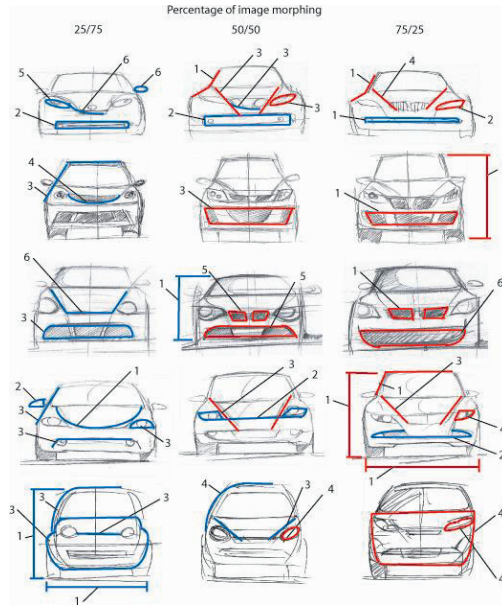


Figure 5. Inconsistencies between polar base images and front view set of five selected morphing sequences as indicated by respondents (Study 2, Part 1). Numerals denote the number of inconsistencies reported for each element as indicated by respondents.

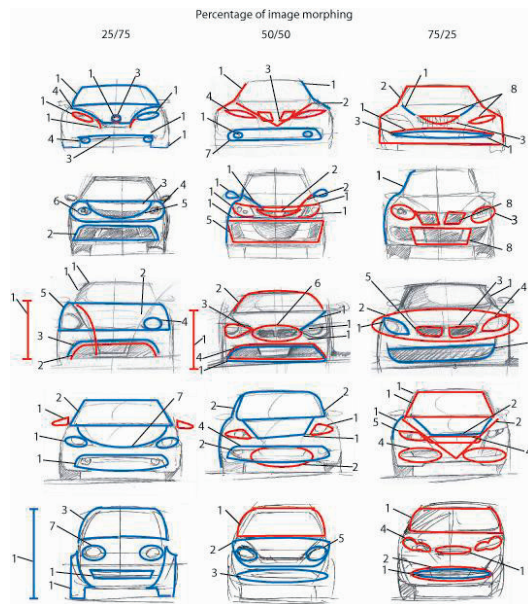


Figure 6. Similarities between polar base images and front view set of five selected morphing sequences as indicated by respondents (Study 2, Part 1). Numerals denote the number of inconsistencies reported for each element as indicated by respondents.

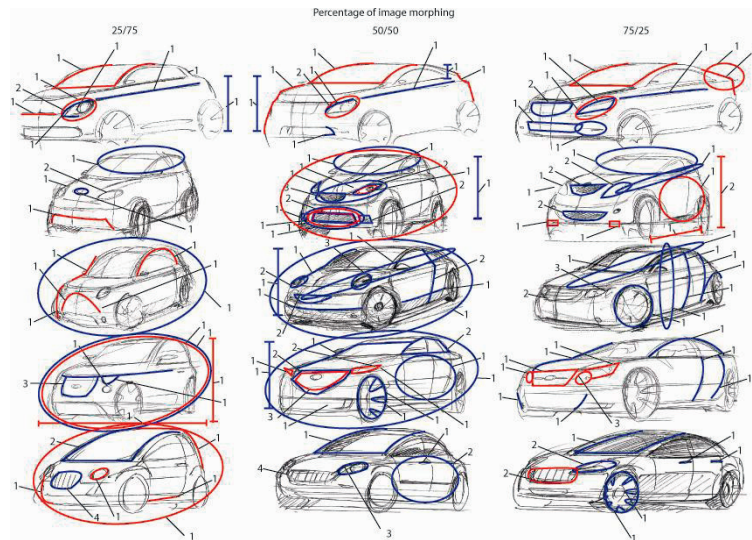


Figure 7. Inconsistencies between polar base images and three-quarter front view set of five selected morphing sequences as indicated by respondents (Study 2, Part 2). Numerals denote the number of inconsistencies reported for each element as indicated by respondents.

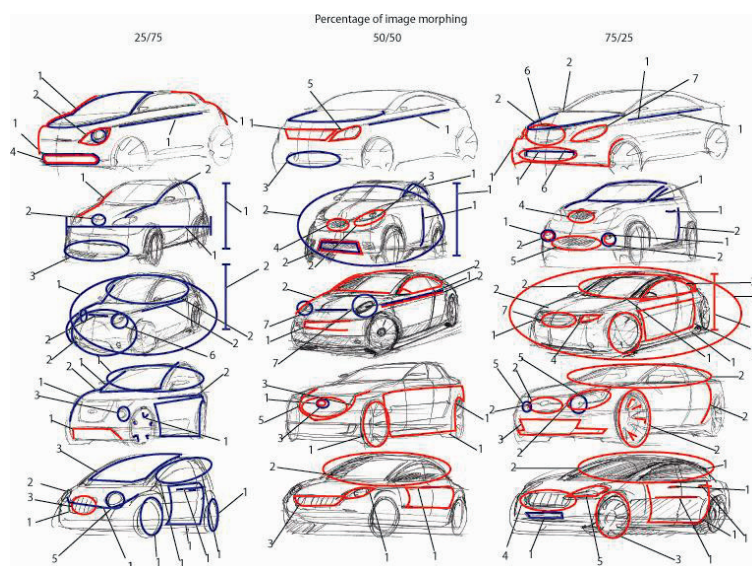


Figure 8. Similarities between polar base images and three-quarter front view set of five selected morphing sequences as indicated by respondents (Study 2, Part 2). Numerals denote the number of inconsistencies reported for each element as indicated by respondents.

process with respect to three characteristics. The first is consistency, describing the variety of output of a morphing sequence, given the same input. Secondly, selectivity, describing the uniform transformation of elements during a morphing sequence. And, thirdly, completeness, denoting the extent to which elements are partially or completely transformed throughout a morphing sequence. For AMS, intrinsic characteristics include absolute consistency, the total absence of selectivity, and total completeness of transformations. In contrast, our findings suggest that designers' morphing processes are characterized by low consistency (a high level of variety between sets of

transformations), a high level of selectivity (some elements are transformed while others are left unattended), and a low level of completeness (elements are only partially transformed throughout the stages of a morphing sequence). This is in accordance with Goel's [4] description of the sketching process – being vague, fluid, ambiguous, and amorphous – characteristics, which are beyond the capacity of current computational systems.

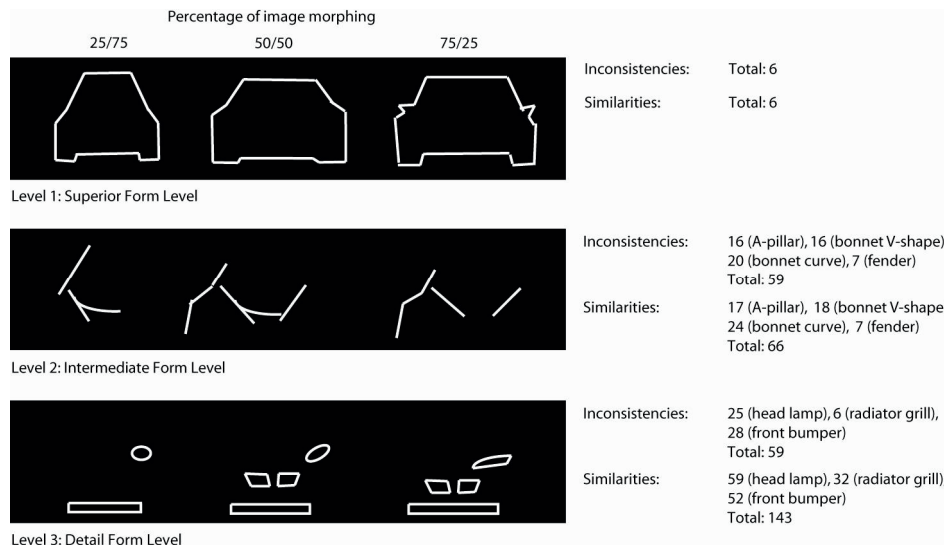


Figure 9. Analysis of form structure levels for the front view set based on heuristic evaluation of all elements indicated by respondents

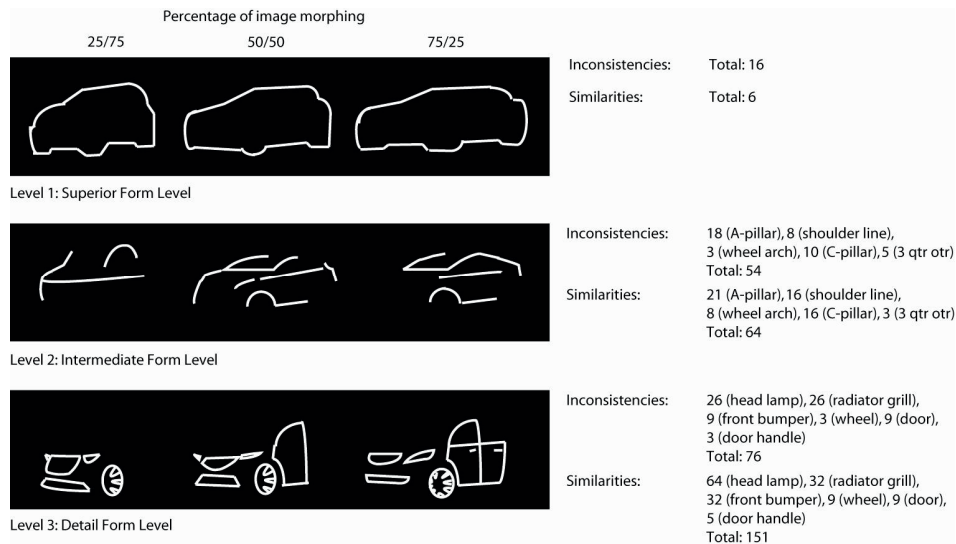


Figure 10. Analysis of form structure levels for the three-quarter front view set based on heuristic evaluation of all elements indicated by respondents

Addressing the first research question, we have shown that manual sketching is characteristically different from AMS with respect to consistency. In contrast to AMS, a designer assigned the same morphing task will not produce an identical result every time. With respect to target performance, i.e. the ability of the designer to realize intent, performance will vary considerably between designers and between assignments, as shown in this research. The introduction of ambiguity to the sketching process is, of course, a natural source of inspiration and variety. Reflective thinking, as described by Schön [16], will lead to new interpretations and present opportunities for new solutions in the process of sketching as performed by the designer. In fact, it seems the designer introduces elements which are of vertical character (i.e. divergent) in interpolative morphing processes, a characteristic which is not found in AMS. On the contrary, AMS will produce identical results time after time, given the same input. From the perspective of producing a variety of solutions, manual sketch work may thus be considered superior.

As proposed in this paper, a major difference between designers' and automated systems' approaches to morphing resides in the recognition and consideration of purpose of form elements. Designers morph through sketching on three levels of form structure: superior level, intermediate level, and detail level. According to Warell [13], form composition is constructed by visual features on all these levels. As suggested by Figures 9 and 10, utility of form elements increases with greater level of detail; hence, on the superior form level, utility is low. Our findings suggest that the amount of transformations, as represented by the number of morphing inconsistencies and similarities, increases drastically with greater level of detail, in the lower orders of form elements. For example, while the number of transformations amount to a total of 22 on the superior form level of Figure 10, it rises to 227 on the detail form level.

In response to the second research question, thus, this finding implies that designers in fact choose what elements to morph, rather than transforming uniformly. In contrast, the behavior of AMS would have yielded the same number of transformations regardless of form structure level. The type of elements selected by designers seems to be characterised by having functional purpose. As a consequence, the inability of AMS to recognize purpose renders them most useful for supporting form generation on the superior level of form. Accordingly, we suggest that automated morphing may be most beneficial for use in design work on the superior level of form generation.

On this level, the main purpose of form is to define the overall gestalt of the product. That is, its function is primarily visual, rather than functional. The visual purpose is shaped and described by the main motif, representing expressive characteristics and defining the typology of the product, a characteristic which is suggested by the work of Chen and Parent [11] (Figure 2). This finding is in contrast to designers' sketches, which suggest that most form transformation (represented by the generation of similarities and inconsistencies) occur at the intermediate and detail levels of product form.

Is utility important in sketching? It may be argued that in the initial phases of form exploration for new product design, utility is not of primary importance. Rather, the search for new stylistic themes, embodying new design formats and generating novel representations, an activity which may be far removed from the focus on utilitarian function, is of core interest. In initial phases, then, AMS may be employed as a means to generate ideas for new shapes at all levels of form composition. However, these shapes will lie in the space defined by the polar images used.

Finally, with respect to the third research question, our findings suggest that designers in fact morph only to a partial degree, exhibiting a low level of completeness in sketch transformation. This is illustrated by Figures 5 through 8. The top row of sketch transformations in Figure 5 exhibits two examples of the low level of completeness in morphing. Going from left to right, the left headlight of the leftmost sketch is only transformed in the first of the three sketches. Similarly, the line indicating the split line between the bonnet and bumper is only transformed in the first two sketches. Going from right to left, the right headlight is only transformed in the first two sketches. The same is true for the bone lines of the bonnet. All these are examples of partial morphing of form elements; a characteristic which would not be found in AMS.

## **6 CONCLUSIONS**

In conclusion, we argue that AMS in its present form (exhibiting morphing behavior with the characteristics of absolute consistency, the total absence of selectivity, and total completeness of

transformations) should be used in an informed manner in design work. This is because AMS have several limitations in relation to manual sketching by designers. These include:

- AMS are not able to search the design space beyond the polar images employed. As such, AMS are strictly interpolative; new shapes will merely be a blend of the shapes defined by the set of polar images. Consequently, AMS are not useful for the generation of novel stylistic themes.
- AMS are unable to recognize and consider purposefulness of form. Hence, visual and utilitarian aspects of form elements are treated identically, resulting in loss of purpose. This effect is most significant at the detail level of form composition.
- AMS are absolutely consistent in the sense that an identical task will produce an identical result every time. Thus, the use of AMS will not lead to variety in solutions, unless polar images are varied. Manual sketch work will, in contrast, produce a variety in output, even if presented with the same task every time.

As a consequence, we suggest that AMS may be most useful for exploring a given theme during what Akner-Koler [3] and Goel [4] refer to as processes of convergent transformation. This typically occurs during the later stages of the styling process. How, then, may AMS be improved to become more useful for early stages of design, often characterized by divergent and explorative processes? A logical solution would be to introduce the ability of AMS to morph selectively and inconsistently, thus introducing ambiguity and variance. This would require AMS to recognize type and purpose of form elements, possibly through the use of approaches such as genetic algorithms or fuzzy logics. Systems with such characteristics are emerging in the field of form optimization, which may provide a suitable development possibility for AMS in the future.

#### **ACKNOWLEDGEMENTS**

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**Paper 6**

**The significance of form elements: A study of representational content in design sketches.**

Abidin, S.Z., Warell, A., & Liem, A. (2010). The significance of form elements: A study of representational content in design sketches. *International Journal of Design and Innovation Research*, 5(3), 47-60.



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# The significance of form elements: A study of representational content of design sketches

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*ABSTRACT. The purpose of this paper is to understand the significance of form elements through the interpretations of design sketches. These interpretations are provided by designers themselves interpreting expressive characteristics of car images, and by students interpreting the sketches of designers' morphing sequences. In the experimental investigation of the sketching process through morphing sequence exercises, designers used individually driven styles and approaches when creating product form. These approaches produce characteristically different form ideas, which differ (but also show consistency) with respect to type of car category, expression, identity, recognition, format, composition, complexity, etc. Typically, assessment of generated sketch work and ideas is done using relative heuristic evaluation in a comparative design review. Given a large set of automotive sketches, general patterns of styling emphasis can be identified. The paper concludes that perceptions of designers are varied due to the representation format of the ideas as visual hand sketches. The visual hand sketches point out certain meaning and can be categorized with respect to perceptual characteristics according to the Product Perception Framework (PPE framework) and suggest that a tool to support evaluation and generation of early design concepts can be developed, and to support the generation of form ideas with desired characteristics for a brand, product category and market.*

*KEYWORDS: Aesthetics, Categorization, Form, Perception, Visual*

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## 1. Introduction

In mature markets, where the functionality and performance of products are often taken for granted, attention is increasingly focused on the visual characteristics of products (Crilly, Moultrie, & Clarkson, 2004). Hereby, design offers a potent way to position and differentiate products as competition intensifies, product complexity increases, and technological



differentiation becomes more difficult (Cova & Svanfeldt, 1993). Significant efforts in recent literature have focussed on investigating specific approaches to innovation and design. The most known approaches are User-centred Design Innovation (Chayutsahakij & Poggenpohl, 2002; Vredenburg, Isensee, & Righi, 2002; Veryzer & Borja de Mozota, 2005), Context-based Design Innovation (Hekkert & Van Dijk, 2003) and Design-driven Innovation. Design-driven Innovation, which plays such a crucial role in the innovation strategy of design intensive firms, has still remained largely unexplored (Verganti, 2008). One explanation for why Design-driven Innovation has largely remained unexplored is that its processes are hard to detect when one applies the typical methods of scientific investigation in product development, such as analyses of phases, organizational structures, or problem-solving tools (Brown & Eisenhardt, 1995; Shane & Ulrich, 2004).

Unlike user-centred processes, Design-driven Innovation is hardly based on formal roles and methods such as ethnographic research. It may be considered as a manifestation of a *reconstructionist* (Kim & Mauborgne, 2005) or *social-constructionist* (Prahalad & Ramaswamy, 2000) view of the market, where the market is not “given” a priori, but is the result of an interaction between consumers and firms. Hereby, users need to understand the radically new languages and messages, to find new connections to their socio-cultural context, and to explore new symbolic values and patterns of interaction with the product.

When targeting competitive advantage using design, Cagan and Vogel (2002) concluded that one of the key attributes that distinguishes breakthrough products from their closest followers is the significant value they provide for users. Several categorisations of value have been suggested. Boztepe (2007) has categorised user value according to utility, social significance, emotional and spiritual value. Utility value refers to the utilitarian consequences of a product. Social significance value refers to the socially oriented benefits attained through ownership of and experience with a product. Emotional value refers to the affective benefits of a product for people who interact with it. Similarly, Sanders and Simons (2009) identified three types of values related to co-creation, which are inextricably linked. These values are monetary, use/experience, and societal.

In most cases, Design-driven Innovation influences value creation of products and services from a cultural and emotional perspective. Explicitly, the social significance value is then being embodied by semantic, syntactic and pragmatic characteristics, which are inherently related to its respective product or service. Re-addressing “Monetary Value”, price positively influences the perception of quality, and willingness to buy. Hereby, the interaction of brand name and price caused subjects to perceive the semantic, syntactic and pragmatic characteristics to be higher in quality and value, and to be more willing to purchase the product than when brand name is absent (Dodds & Monroe, 1985). Within this context of “Value Creation” and “Design-driven Innovation”, it is therefore necessary to introduce a framework of product experience (Crilly, Moultrie, & Clarkson, 2004), in order to better understand the significance of form elements and how these form elements can enhance the development of brand attributes.

## 2. Representational issues with respect to car design

A car’s design character is typically obtained by sequentially modifying a neutral car according to the designer’s tastes and objectives. Considering the car as a 3D volume and the size of the wheels as a unit for measuring of volumes, the designer normally focuses on some typical entities and moves them away from the average. In the designing process, wheels are the first entities designers focus upon, before drawing the whole car around them (Tovey, Porter, & Newman, 2003). This structured approach in the overall development of a car is common practice, because the product is constrained to strict

engineering/technological requirements. From a design practice perspective, all curves successively created in the two-dimensional (2D) sketch are then aimed at defining a specific volume that is rendered a second time, adding lights and shades, enforcing the curvature effects, and so on to express the stylist's intent and character of the car. For instance, designing and sketching practice in collaboration with Pininfarina Ricerca e Sviluppo team (see Catalano, 2004) showed that there are three aspects in the automotive field, which play a decisive role in product synthesizing and judgment. They are:

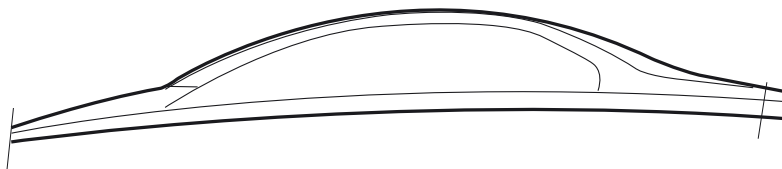
- Graphics, i.e., some details of the car or the color;
- Treatment, i.e., the character of surfaces and leading lines;
- Volume, i.e., proportions and the mass distribution (Cheutet et al., 2005).

The following design examples below illustrate what is meant by "Treatment" and "Volume" in the profile view.

Curves encompass the roof line, the waist (or belt) line, and the front and rear panel overhangs. By definition, the waist line is the curve dividing the side windows and the body side, while the overhang is the distance between the front or rear end of the car and the centre of the front or rear wheel, respectively. In practice, it is the curve (accent line), rather than the waist line, that is considered for character evaluation. Actually, the accent line may be a light line; a curve only perceived when light is reflected.

However, initiatives to consciously introduce representational issues in the design and brand development have been limited. Although some line work and surface generation in certain car designs has proven to be effective and meaningful in the development of brand identity and explanation of semantic (meaning carrying) and syntactic (structure establishing) qualities (see Figure 1) (Karjalainen, 2007; Warell, 2001), the need for connecting car features to representations to gain greater awareness in car designing and branding has not yet been thoroughly established.

The aim of this study is to develop consciousness among designers when they generate car designs in terms of recognition, comprehension and association.



**Figure 1.** The side-shoulder, also known as the 'catwalk,' carries semantic and syntactic functionality of the Volvo form language (see Warell, 2001).

### 3. Perceptual experience

The human experience of visual space includes knowledge relating to the size, shape, location, and distribution of entities in stable three-dimensional (3D) environment. In the 3D environment, it seems the perceptual system and processes facilitate the sense-perceptory and brain mechanisms that process perceptual information, giving rise to spatial experience. According to Evans and Chilton (2009), perception consists of three stages: i) *sensation*, ii) *perceptual organization*, and iii) *identification and recognition*. Sensation concerns the way in which external energy, such as light, heat, or (sound) vibrations are converted into the *neural codes* which the brain recognizes. Perceptual organization concerns the way in which this sensory information is organized and formed into a perceptual object, a percept. Identification and recognition relates to the stage in the process whereby past experiences and conceptual

knowledge are brought to bear in order to interpret the percept. For example, a spherical object might be identified and recognized as a football or a coin, or a wheel, or some other 'circular' object.

According to Dewey, experience is not something that is totally internal to the individual. Rather, *"an experience is always what it is because of a transaction taking place between an individual and what, at the time, constitutes his environment"* (p.43) (see Cooper, 2001). Experiences are context- and situation-specific; which means they change from one set of immediate circumstances, time, and location to another. In a similar way, value changes as cultural values and norms, and external contextual factors, change (Boztepe, 2007). Focussing on the product, Hekkert (2006), claims that its function can very well be experiential; for instance to enjoy, enrich, inspire, and strengthen one's identity, and many believe such experiences are nowadays more decisive in people's buying behavior than the product's primary or utilitarian function. Therefore, making all the sensory messages congruent with the intended, overall experience is an important task for designers. In line with Crilly (2005), it is assumed that communication through product design occurs through the embodiment of designer intent in the form of products, and through the subsequent interpretation of meaning by the public.

Product experience is subjective and specific to each perceiver, and depends on personal factors (experiences, background, cultural values and motives), product related factors (type of product, properties and characteristics, brand), and external factors (environmental, social and economic context). A variety of aspects of product experience, as well as frameworks, have been proposed by a range of authors (Crilly, Moultrie, & Clarkson, 2004; Lewalski, 1988; Jordan, 2000; Heufner, 2004; Norman, 2004; Desmet & Hekkert, 2007).

In this work, we have adopted the framework of Perceptual Product Experience, the PPE framework (for more detail, see Warell, 2008), as a model for analysis. This framework considers modes of product experience, and dimensions for representing the product. Perceptual product experience is described as being composed of three core modes; the sensorial, the cognitive, and the affective modes of experience, and two dimensions; the dimension of presentation and representation (see Figure 2). In the following sections, the modes and dimensions of the PPE framework are briefly described.

The three core modes recognize all possible types of perceptual experience; including initial impression and recognition of product existence and specific perceptual characteristics (the sensorial mode); making sense of the product, its manifestation, structure, use, origin and purpose (the cognitive mode); and the affective response, attribution of value to, and judgment of the product (the affective mode).

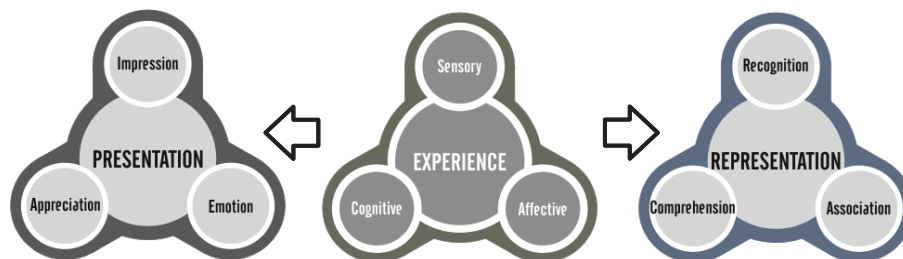
The dimension of presentation is concerned with the direct, sensual stimuli related side of the experience. This may be seen as the 'pleasurable' side of the experience, related to the direct, non-interpretative experience, and includes the impression, appreciation and emotion submodes.

In this paper, we are interested in the significance of form elements as interpreted by designers, which relates to the dimension of representation. In this dimension, the product experience is regarded as a meaning-making phenomenon that can be described by the three submodes of 'recognition', 'comprehension', and 'association'. The process of meaning making is socio-culturally contextualised and can be seen from the perspective of the producer (e.g., the designer or company) and the perceiver (e.g., the customer or user). The representation submodes can be explained through Peircean sign theory (Peirce, 1931-1966) and are described in the following:

The first mode, recognition, is based on familiarity, resemblance or similarity, and requires previous precedents to compare with (i.e., iconic sign references). Thus it is dependent on the existence of pre-established references stored in long term memory (Simon, 1992; Solso,

1999). Recognition of product type and brand requires resemblance to other products through similar sensorial elements. In the visual domain, such elements are known as 'signifiers' or 'design cues'. For example, the characteristic 'kidney' front grille of a BMW is an example of design element which identifies the BMW brand through iconic recognition.

Comprehension, the second mode, is about making 'sense of things', such that products are "understandable to their users" (Krippendorff & Butter, 1984). Through comprehension, we understand characteristics such as level of quality and nature of the product; the product describes its operation, expresses its properties, and exhorts certain types of action or even non-action; it informs and advises about itself. In comprehension, perceivable references in the product point towards the product itself, providing meaning related to the nature, behaviour, properties and essential physical characteristics of the product. Semiotically, indexical and symbolical signs create references for comprehension of the product. For example, a typical door handle is an example of an indexical sign, describing operation and function. The hard and shiny quality of a stainless steel surface or the sturdiness expressed by a Jeep, are examples of symbolic references, referring to the nature of the product.



**Figure 2.** Framework of perceptual product experience (PPE framework), with core modes (centre) and the two dimensions of presentation (left) and representation (right) with submodes (Warell, 2008).

Finally, the third mode, association, is about communication of, e.g., values, origin and heritage. Association is dependent on subjective and socio-culturally conditioned processes of coding, which determine how we create references with meaning through symbolic signs within groups with similar values and aspirations and interpretative communities (Chandler, 1994). In association, meaning is created (encoded) and interpreted (decoded) from two perspectives; from the point of view of the manufacturer, who uses the product to convey strategic brand messages and build brand values (Karjalainen, 2004); and from the point of view of the customer or user, who communicates personal values and preferences through ownership or use of the product. The classical, aristocratic values and the racing heritage imbued by a Jaguar are examples of symbolic association.

The representation dimension of the PPE framework is intimately related to product identity (Warell, 2006a; Warell, Fjellner, & Stridsman-Dahlström, 2006b) according to the following, with respect to identity references for each sub mode:

- Recognition (of Type): "What the product is" (function, use, purpose, maker)
- Comprehension (of Characteristics): "How the product is" (properties, performance, behaviour, mode-of-use)
- Association (to Values): "What the product stands for" (origin, brand, heritage, user)

Consequently, a product with strong representational qualities in all three sub modes will most likely be perceived as having a strong and clear identity.

#### 4. Objective and method

The objective of this research is to investigate how respondents interpret sketches made by designers with respect to representational characteristics. Research questions explored in the study are:

RQ1: What associations are evoked by photographic representations? How do the associations differ between designers and respondents? (In relation to the PPE framework, this question addresses the comprehension and association modes)

RQ2: What expressions are conveyed by sketch representations? What elements carry these expressions? (In relation to the PPE framework, this question addresses the comprehension mode)

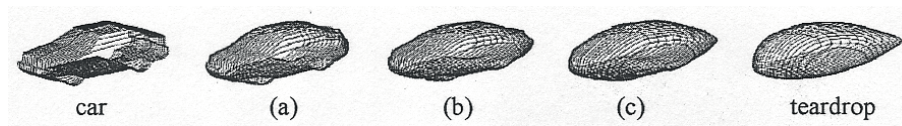
RQ3: What visual brand references are carried by the sketches? (In relation to the PPE framework, this question addresses the recognition and association modes)

Two complimentary studies were performed in order to answer these research questions. The first study involved a sketching assignment for practising industrial designers in the automotive industry. The second study involved an elicitation assignment for product design students, based on the sketches produced in the first study.

##### 4.1. Study 1

In Study 1, a total of 43 selected automotive designers in the United Kingdom, Norway, Sweden, and Malaysia were first asked to assign a keyword for a set of front view and three-quarter front view images of selected automotive designs. Each polar image consisted of a grayscale photograph of a production car currently available on the world market (Figure 4).

Secondly, they were given the task of performing morphing sequences for the two views, using manual freehand sketching. Morphing in this paper refers to the shape interpolation (blend shapes, morph targets, and shape interpolation), which is the most intuitive and commonly used technique in shape animation practices (see Figure 3). A blend shape model is simply the linear weighted sum of a number of topologically conforming shape primitives (see Chen & Parent, 1989; Abidin, Warell, & Liem, 2011; Deng & Noh, 2008). We assigned designers to produce morphing sequences, each consisting of three sketches, representing the 25%, 50% and 75% transformation stages, respectively, based on two photographic polar image references. In the assignment, designers gradually morphed from the left image to the right polar image in three consecutive steps. Using this technique would allow later analysis to identify the transformation of specific elements in each sketch, carrying representative characteristics according to the PPE framework. Each designer carried out the assignment individually at their work premises.



**Figure 3.** Morphing; weighted average shapes from a car to a teardrop shape for the ratios of (a) 70/30, (b) 50/50, and (c) 30/70 (Chen and Parent, 1989).

##### 4.2. Study 2

In the second study, a total of 10 respondents; all final year, masters level product design students, analysed the morphing sequences produced by the designers in Study 1. Firstly,

the respondents were given the task to identify the car brand and to assign a keyword expressing their spontaneous reaction to each photographic polar base image (Figure 4). They were also asked to list three expressions evoked by the images, and to indicate (using a pencil) three characteristic visual features for each brand.

Secondly, a selection of view sets (front view and three-quarter front view) by five different designers was made by the authors, based on a heuristic quality review. Each view set was represented by five separate morphing sequences of three sketches each. Each respondent participated in two tests. In Test 1 respondents assessed the five sets of front view sketches, while in Test 2, respondents assessed the five sets of three-quarter front view sketches. In total, each respondent assessed 150 sketches. Each student carried out the assignment individually at the university premises.



**Figure 4.** Polar base images used in the study (brand and model identifiers were not provided to respondents).

The respondents were given the five sets of morphing sequences for each view. The morphing sequences of three sketches each were presented one at a time. Thus, in total, ten morphing sequences were presented to each respondent. For each sequence of morphing sketches, the respondents were asked to indicate features carrying the same expressions, as well as features evoking the same associations, as stated previously. Respondents indicated features using colored pencils on grayscale A3 paper printouts of each morphing sequence.

In addition to the annotated sketch material provided by the respondents, the study was recorded using digital audio and video equipment for reference during subsequent analysis.

## 5. Results and discussion

In this section, the findings of the analysis of Study 1 and Study 2 are presented. The analysis aimed to ascertain what types of elements are perceived to have representational meaning with respect to recognition (iconic references), comprehension (indexical and symbolic references), and associations (symbolic references), according to the categorizations of the PPE framework. During the analysis, responses from respondents were categorized according to the types of representation of the PPE framework and mapped to each representational sub mode (recognition, comprehension, and association, respectively).

The results are summarized and discussed in the following. The presentation is divided into interpretations of photographic base images and of sketch morphing sequences, respectively.

### ***5.1. Interpretations of photographic base images***

With respect to the first research question (what associations are evoked by photographic representations, and how do the associations differ between designers and respondents?), a very wide range of interpretations was evoked. Although some responses did match, no clear correlations between designers and respondents could be identified. Since the associative field is of very wide range and dependent on subjective, cultural and contextual variations, this finding is not unexpected. The PPE framework did however assist in revealing these differences, and it is possible that more homogenous groups of subjects would have yielded a more coherent result.

The Volkswagen New Beetle, BMW 3 series and New Fiat 500 were recognised correctly, whereas the recognition of the Acura RL 500 was misinterpreted (not identified correctly with respect to brand).

In terms of comprehension, the New Beetle was perceived as generally pleasant and fun. The BMW 3-series represented masculine traits such as strength, aggression, dominance, etc. The Fiat 500 resembled the New Beetle, but was comprehended as less positive concerning the level of communicated confidence. The Acura RL shared the same traits as the BMW 3 series, but was complemented with some negative perceptions, such as inconsistent, cheap, and dull.

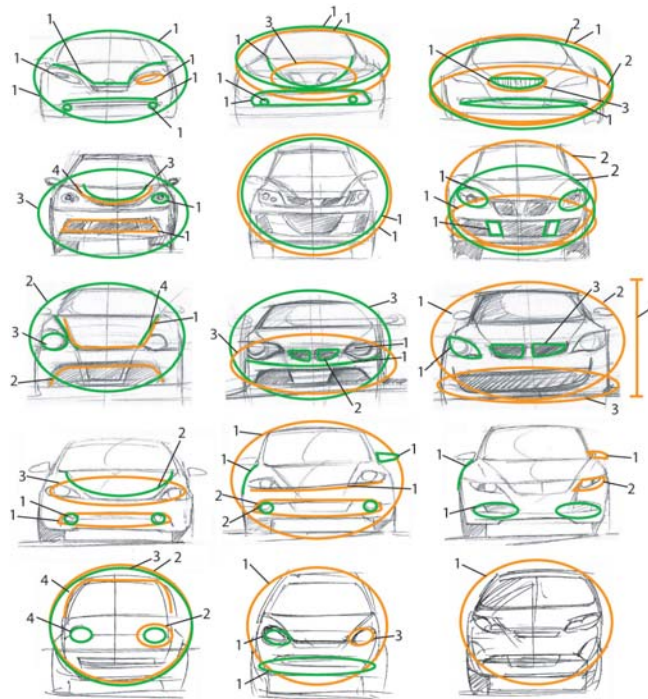
From an association perspective, the New Beetle was perceived to appeal to young singles and families, who are fun-loving, have the interest and economic capacity to spend on safety and quality. They were also perceived to have a sense of nostalgia. The customers of the BMW 3 series were perceived as being male-oriented, profiled as professional individuals valuing superior technological quality. For the Fiat 500, associations seem to be contradicting. On one hand, young, energetic and sporty individuals, who are Mediterranean inspired and are inclined towards an urban lifestyle are seen to have an affinity for the car. On the other hand the car is being associated with low-cost and low quality characteristics. In terms of associative characteristics, the Acura RL resembles that of the BMW 3 series, however, connotations, such as Asian, boring, value for money, and conservative, negatively influence the perception, concerning the dynamic and quality impact of the car.

### ***5.2. Interpretations of sketches***

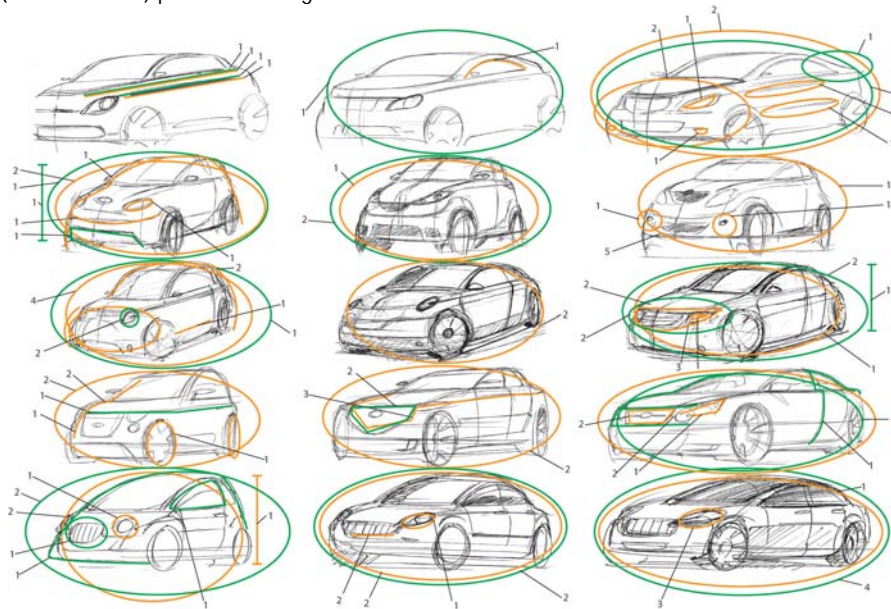
As mentioned earlier, a total of 150 sketches were assessed by respondents. The method of assessment generated qualitative material for analysis, including annotated sketches with pencil markings indicating features carrying representative qualities as interpreted by the respondents, and basic descriptive quantitative material derived from summations of markings in different representational categories (i.e., the three representation modes of the PPE framework). The analysis generated approximately 49 A4 pages of tabulated material, including verbal comments and visual sketch material with annotated features, categorised according to the three representational modes (recognition, comprehension, association). Figures 5 and 6 provide examples of the collated annotated sketch material.

#### ***5.2.1. Findings (front view)***

Overall, the front view test yielded fewer responses than the three quarter front view test. This may be due to a lower level of sketch complexity, resulting in a smaller number of sketch features.



**Figure 5.** Collated responses to research questions 2 (orange annotations) and 3 (green annotations) based on interpretations from respondents. Each row represents a selection of front view morphing sequences by different designers for left (VW New Beetle) and right (BMW 3-series) polar base images.



**Figure 6.** Collated responses to research questions 2 (orange annotations) and 3 (green annotations) based on interpretations from respondents. Each row represents a selection of three-quarter front view morphing sequences by different designers for left (Fiat 500) and right (Acura RL) polar base images.



On an average across all representational modes, respondents indicated between 1,6 and 2,1 features for each sketch image. Indicated features included specific detail form elements as well as overall form on the gestalt level.

Compared to three quarter front view responses, more features in the comprehension mode were indicated for the front view sketch sequences. Possibly, this may be due to respondents being more familiar to interpreting expressive properties in the front view of cars, which is often referred to by automotive designers as the 'face' of the car.

For the research questions, the specific findings were as follows:

*RQ2. What expressions are conveyed by sketch representations? What elements carry these expressions?*

- In the comprehension mode, the VW New Beetle generated a much stronger response, in terms of the number of interpretations, compared to the BMW 3-series.
- In terms of comprehension, respondents reported a gradual decrease in expressed femininity for morphing sketches towards the right polar base image (the BMW 3-series).
- Expressions for the 25% transformation of each polar image included:  
 VW New Beetle: Retro, Confident, Funny, Cute, Happy, Nice, Calm, Fast, Soft  
 BMW 3-series: Serious
- Comprehension elements for the 25% transformation of each polar image included:  
 VW New Beetle: front lights, bonnet outline, front air intake outline, front fascia, glasshouse silhouette  
 BMW 3-series: front fascia, grille outline, frontal silhouette, front light outline, front air intake pillars, height ratio, side rear view mirror

*RQ3. What visual brand references are carried by the sketches?*

- Recognition of brand is determined by outer shape, bonnet line and headlamps.
- The recognition mode received the strongest response in terms of the number of interpretations. This was true for both polar base images (VW New Beetle and BMW 3-series).
- No general conclusions can be made regarding the association mode, due to the small number and contradictive nature of responses.
- Recognition elements for the 25% transformation of each polar image included:  
 VW New Beetle: Headlight outlines, fog lights, bonnet outline, front fascia, front air intake outline, frontal silhouette, glasshouse silhouette  
 BMW 3-series: Headlight outlines, front fascia, grille outline, frontal silhouette, front air intake outline, height ratio, side rear view mirror, fender curves
- Associations for the 25% transformation of each polar image included:  
 VW New Beetle: Looks like a frog, Unfriendly, Friendly person with soft qualities  
 BMW 3-series: Established, Looks big

### 5.2.2. Findings (three-quarter front view)

Overall, respondents indicated a significantly larger number of responses in the recognition mode, followed by comprehension and association. The reason for this may be methodological, as indicating explicit and characteristic iconic elements (recognition mode) using pencil markings on sketch reference images lends itself more naturally than indicating more implicit and inherent qualities such as expressions (comprehension mode) and values (association mode). This aspect was however considered in the method, as it also allowed respondents to respond qualitatively using free text as a complimentary option. However, it may be more useful for the study of symbolic references to use other methods, such as interviews or visual, associative elicitation methods.

From the 10 respondents, the number of responses on each of the three modes "Recognition", "Comprehension" and "Association" were less than five for each morphing sequence. On an average across all representational modes, respondents indicated between 1,6 and 2,5 features for each sketch image. Indicated features included specific detail form elements as well as overall form on the gestalt level.

Across all morphing sequences, a considerably stronger response was indicated for the left base image (Fiat 500). More representational qualities were reported for each mode, which was indicated by more features and more symbolic associations compared to the right polar image (Acura RL).

For the research questions, the specific findings were as follows:

*RQ2. What expressions are conveyed by sketch representations? What elements carry these expressions?*

- The comprehension mode (expressive and descriptive qualities) is considerably stronger for the Fiat 500 than for the Acura RL. Stronger expressions and more references were generated.
- Expressions for the 25% transformation of each polar image included:  
     Fiat 500: Aggressive Confident, Cute, Retro, Stupid, Joy, Humble, Innocent, Feminine, Practical, Simple, Funny  
     Acura RL: Speedy, Macho, Exclusive
- Comprehension elements for the 25% transformation of each polar image included:  
     Fiat 500: Bone line, Belt line, front lights, silhouette, top bumper split line, front façade, wheel outline, height ratio  
     Acura RL: side blisters, front fascia, C pillar, front lights, overall silhouette, grille outline

*RQ3. What visual brand references are carried by the sketches?*

- Recognition of both cars is determined by the overall outer shape, features and components
- Recognition elements for the 25% transformation of each polar image included:  
     Fiat 500: Waist-line, Bone-line, Belt line, Pillar line, Wheel, Headlamp, Bumper-line, Fender curves, A-pillar shape, Overall Shape, Front fascia, Front overhang  
     Acura RL: C-Pillar, Door-line, Radiator Grill, Bonnet-line, Bumper-line, Overall shape, from Fender curves to A-pillar

- Associations for the 25% transformation of each polar image included:

Fiat 500: Inexpensive, Like a child, Like a mouse, Resembles a toy

Acura RL: Expensive, Shaped, High class person

## 6. Concluding discussion

The objective of the study was to understand the significance of form elements through the study of representational content of design sketches. The central proposition was made that people interpret sketches with respect to representational qualities through semiotic interpretation. According to the typological categorization of representation of the PPE framework, such qualities include recognition (iconic references), comprehension (indexical and symbolic references), and associations (symbolic references).

Although perceptions of designers and respondents are varied due to the representation format of the ideas as visual hand sketches in the morphing process, the PPE framework is still considered a useful tool for establishing familiarity, understanding quality characteristics and nature of the product and finally determining meanings and assessing values of form elements.

This suggests that within the context of incremental design development (morphing), which is prevalent in the car design industry, a tool to support evaluation and generation of early design concepts may be developed based upon the PPE framework. The tool could be a tool box in a CAD software like “representational softwares” that support qualitative elements through Recognition (of Type), Comprehension (of Characteristics), and Association (of Values) specifically conceived for car design development phases. Furthermore, these findings could open new research paths – e.g., new guidelines to be applied in sketching phases or questionnaires/pictures to be proposed to producers, customers and users.

Once such a tool can be realised within an extended framework of product experience, the business concept of “Value Creation” and “Design-driven Innovation” can then be better understood in relation to the significance of form elements and how these form elements support the communication of brand attributes.

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