A model for haptic aesthetic processing and its implications for design

Claus-Christian Carbon\textsuperscript{1,2}
\textsuperscript{1}Department of General Psychology and Methodology
University of Bamberg, Bamberg, Bavaria, Germany
\textsuperscript{2}Department of Psychology
University of Pavia, Pavia, Lombardia, Italy
ccc@experimental-psychology.com

Martina Jakesch\textsuperscript{3}
\textsuperscript{3}Department of Basic Psychological Research
Faculty of Psychology
Vienna, Austria
martina.jakesch@univie.ac.at

Abstract—Research in aesthetics typically focuses on static stimuli or stimulus properties from the visual domain leaving unanswered a great many questions on haptic aesthetics. The present paper aims to give a short impression of the relevance of aesthetics for design and everyday-life decisions, then focuses on phenomena concerning haptic aesthetics in particular, for instance top-down processes and mere exposure effects. Based on empirical findings and theoretical considerations with regard to haptic research, the paper develops a functional model of haptic aesthetics which is explained step-by-step. This model assumes a continuous increase of elaborative processing through three subsequent processing stages beginning with low-level perceptual analyses that encompass an initial, unspecific exploration of the haptic material. After a subsequent, more elaborate and specific perceptual assessment of global haptic aspects, the described process enters into deeper cognitive and emotional evaluations involving individual knowledge on the now specified haptic material. The paper closes with an applied view on design issues to explicate the importance of integrating haptic aesthetics into corresponding approaches.

Keywords—Aesthetics; haptics; tactile; cross-modal; liking; preferences; cognition; perception; sensitivity; art; pleasure; appreciation

I. INTRODUCTION TO EMPIRICAL AESTHETICS

A. Relevance of aesthetics

Empirical aesthetics is a young science but a very old subject of human interest. To understand what people appreciate, like, love or prefer and why they do so is of essential relevance for everyday life events where a clear rational basis for decision making is often not available. For instance, aesthetic aspects play a dominant role in choosing specific food or beverages: good-looking, immaculate tomatoes might be preferred just because of their level of color saturation while important factors like price, ecological footprint or amount of contained vitamins are ignored—a reason why companies have developed the use of special illumination in the fresh food sections of supermarkets to accentuate the offered tomatoes’ reddishness and to reduce the visibility of visual flaws on their surfaces. In sectors where products are quite interchangeable as a consequence of similar technical specifications, consistent legal requirements and production constraints, aesthetic aspects are particularly powerful [1]. Technical innovations in cars, to mention just one example, can spread from one company within a short period of time due to the taking out of patents by competitors or the cloning of innovative technology. Most car brands, however, still have an idiosyncratic “Formensprache” (design vocabulary) [2] which is a key indicator of brand identification and, thus, can be utilized to generate important brand associations. In fact, a significant number of everyday-life decisions that are clearly more important than rather trivial product selections are made on the basis of aesthetic factors, e.g., the decision about where to settle, which politician to elect or with whom to start a family [3]. In this article, the term ‘haptic aesthetics’ is defined as capacity (of materials and objects) to please our haptic system [4].

B. Aim of the present paper

In most areas of perceptual sciences, the scientific effort made to systematically understand phenomena is dominated by research on visual dimensions. This also holds true for empirical aesthetics: Most aesthetic theories are consequently inspired by visual phenomena and are only tested with regard to visual effects. The present paper aims to extend this vision-centered view and proposes the integration of a haptic perspective. Even early pioneers like Johann Gottfried Herder [5], who discussed the relevance of touch for sculptures, mentioned that the impact of the sense of touch is underestimated in society. This statement is also true several hundred years later. Therefore, we will (1) give a brief overview of aesthetic phenomena in the haptic domain, (2) develop and explain in detail a functional model of haptic aesthetics, and (3) develop an applied perspective of haptic aesthetics with regard to design-relevant questions including a case study to demonstrate the impact of haptic aesthetics on a specific design issue.
II. HAPTIC AESTHETICS

A. An extraordinary modality: Haptics

Besides its important role of protector against negative environmental influences, the skin provides a variety of powerful detectors, among them detectors that constitute the tactile, tactual or haptic sense. Due to its early onset during intrauterine development, the haptic sense enables first contact and communication with the external world. Even at this early point, an essential aspect of the nature of the haptic sense becomes apparent: its inherent responsive and reflexive quality. As soon as you touch (something or somebody) you will in turn be touched yourself [6]. Thus, every haptic inspection directly affects the inspected target as well as the inspecting agent. The emerging direct feeling might be one reason for the occurrence of strong personal experiences linked to touching, and consequently being touched, and might further create the implicit need for touch that can, for example, often be observed in museums: We stand in front of a sculpture that has an “inviting” surface or intricately arranged curves, but which is accompanied by a “DON’T TOUCH!”-notice presented in big letters [see also 7]—and we nevertheless feel that it is necessary to touch the object; and consequently we end up doing so.

Why is the need for touch [8] often so imperative? Why are we not able to resist touching in so many instances? Why do we need to touch in order to gain real proof of certain product qualities? The answers are certainly manifold, but there are two candidates that seem to be very promising: 1) Haptics’ interactivity and 2) Haptics’ multi-methodologies.

1) Haptics’ interactivity

Haptics is the only human sensory modality that can rightly be thought of as being “active”. Whenever haptic processing is needed, we actively inspect an object and, by doing so, get in physical contact with it. Quite academically, Gibson [9] differentiated between active and passive touch: Active touch refers to the concept of touching (the perceiver brings about the tactile impression on the skin herself), whereas passive touch refers to being touched (the perceiver’s tactile impression is induced by an external object). The real magic behind both concepts is their inherent interactivity, as both kinds of touch are in fact not fully separable. Touching is always accompanied by being touched (and vice versa); in fact, this is the reason why we can use the haptic sense for refining and reprogramming our motor programs. Equipped with such a capable sense we mainly use it in an exploratory manner. If we encounter a totally dark, silent, odor-free environment we can nevertheless feel that it is necessary to touch the object; and consequently we end up doing so.

2) Haptics’ multi-methodologies

Haptic exploration is not only marked by interactivity but also by high complexity as humans can process haptic qualities in a multi-methodological way. Sonneveld and Schifferstein [6] offer an overview of different approaches of haptically exploring the world based on Lederman and Klaztky’s [10] exploratory procedures [cf. 11]. Typical exploratory movement patterns are:

1. lateral motion for scanning texture,
2. pressure for revealing hardness,
3. static contact for assessing temperature,
4. unsupported holding for estimating weight,
5. enclosure for investigating global shape and volume,
6. contour following for detecting the shape.

These clearly distinguishable but at the same time combinable explorative procedures are enabled by a complex interplay of processes in cutaneous channels (mechanoreceptors and thermoreceptors located in the skin) and kinesthetic or proprioceptive receptors (located in the muscles, muscle spindles and tendon organs) [12, 13].

B. Haptic aesthetics

Haptic aesthetics is one important aspect of the more general mechanism of haptic processing or “tactual” experience [14] that has the potential to create the typical ‘gut feelings’ marked by clear-cut evaluation and qualification of the material without the need or ability to use complex verbal descriptors as in visual aesthetics [15, 16]. Such gut feelings are often relevant for product experience and, ultimately, for selecting specific target products in a real-world context. One main reason for the direct affect via haptics might be direct physical contact with [17] as well as direct physical feedback from the inspected object [18]. Several experiments have demonstrated the strong impact of haptic aesthetics on consumer choice and consumer preferences: For instance, barriers fixed to constrain touching at retail displays can inhibit the principal possibility of appreciating and evaluating on a haptic level which leads to less confidence in product evaluations [19]. Retailers can directly benefit from allowing customers to touch their products as it also can positively affect the costumers’ persuasion [20, 21], a finding already revealed by several experimenters in the 1980s: Mehrabian [22], e.g., showed that active approach behavior can positively influence liking, preference, and attitude towards objects; Heslin and Alper [23] proposed that “touching does, indeed, cause liking” (p. 63). Revealing that consumers with a greater need to touch even avoid buying products on the internet purely because of the lack of opportunity to evaluate them on a haptic aesthetics basis, Citrin, Stem, Spangenberg
and Clark [24] explicated a major challenge for retail concepts that work on a solely virtual basis.

Despite the clear relevance of haptic aesthetics with regard to appreciation in general and appreciation of design products in particular, systematic knowledge on this topic is quite sparse and a widely accepted framework theory of haptic aesthetics is still lacking. A Web of Science literature search conducted on 27th April 2012 yielded only two research papers on haptics & appreciation and four on haptics & aesthetics (combined title search). In the present paper we would like to establish the idea as well as the concrete technical term of “haptic aesthetics”. As a theoretical framework for this specific part of aesthetics it is imperative to obtain a more holistic view on aesthetics and product experience. We will, furthermore, develop a functional model of haptic aesthetics.

III. A FUNCTIONAL MODEL OF HAPTIC AESTHETICS

To meet the obvious importance of haptic aesthetics for adequately understanding and describing the process of object or product evaluation, it is essential to establish a framework model offering a basis for explaining typical phenomena of haptic aesthetics – thus, providing a framework for systematic future research. Further, such a model should enable the assignment of different sub-processes to well-defined processing stages for which the complex, interactive and integrative process resulting in a haptic aesthetics experience is built up.

A. General structure of the model

The “functional model of haptic aesthetics” (see Figure 1) is structured as a series of processing stages marked by a continuous increase in specificity, complexity and elaborateness. It therefore focuses on the internal processes of a perceiver. Importantly, besides feed-forward processing, recursive loops can change the current process itself via top-down control resulting from successful processing of main aspects of the regarding stage. These loops are defined with regard to the aspects context, expectation, integration and familiarity. The input of the model is a haptically unspecified object; the output after three levels of elaboration is the haptically specified object. To roughly outline the content of the proposed stages and their connection to existing directions in haptic research: The first two stages (1. low-level analyses: exploration; 2. mid-level analyses: assessment) refer to basic local and global processes in haptic perception in accordance to psychophysics dating back to the famous studies of Ernst Heinrich Weber but also more recent haptic object recognition theories (please see the following section for more details). The third stage (high-level analyses: evaluation) discusses cognitive and emotional aspects in processing. It is the one connected mostly to the aforementioned early directions in philosophy like Herder (aesthetic evaluation) but is also related to approaches in product design (utilization and aesthetic evaluation) [e.g., 4, 6, 25, 26, 27]. The present selection of variables is based on the currently existing findings in haptic aesthetics but mostly on those in visual aesthetics [e.g., 28, 29].

B. Three levels of elaboration and their feedback loops

Feedback loop 1: Context feedback loop.

The initial input of haptic aesthetic processing is an object that has not yet been haptically specified, but that is accompanied by important information provided by the context. The context can be given by the situation in which the object is processed, the place where it is situated, the task the perceiver has to fulfill, the cultural setting the perceiver is in or simply by any kind of information communicated about the current object. These contextual cues have the potential to change the initial processing of the object itself by providing information that leads to a specific way of processing, to change the entry point of processing or even to cancel further processing due to avoidance. An example of how contextual cues can influence the way of processing an object from the start was shown by Jakesch and colleagues [30, 31]. They demonstrated in a within subject design that identical materials received different aesthetic and material related judgments according to the absence or presence of specific “scenarios” (contextual cues e.g., steering wheel) under various modality conditions (haptic, haptic plus vision, vision). Less positive contextual cues may result in an abortion of processing e.g., ignoring the stimulus if not enough interest is induced or the person in charge fears penalization (e.g., because touching the object is forbidden or might be harmful) or danger (being hurt by touching the object). Typical effects of this kind demonstrate the context feedback loop in action. Thus, as a result of contextual information, the very same object can be perceived and processed differently resulting in correspondingly varying aesthetic responses. The impact of context will be shortly discussed also in the level descriptions.

1) Level 1: Low-level analyses (exploration)

The first level of elaboration can be described as simple, unspecific processing encompassing all kinds of low-level perceptual analyses that can be executed without specific knowledge of the target object. Based on different approaches to classify actual exploratory strategies, mainly inspired by pioneering work of Klatzky and Lederman [32, 33] (see also Figure 2) and recent descriptions by Sonneveld and Schifferstein [6] combined with haptic procedures described by Renault’s patented Sensotact® tactile test system [see for details and evaluations of this reference system 31, 34, 35], we differentiate between three main types of low-level analyses in which haptic qualities are processed in a relatively local fashion.

These three main types of analyses are termed explorations as the quality of object processing is quite unspecific:

a) Orthogonal exploration

Orthogonal exploration refers to all haptic qualities that can be detected and explored by orthogonal finger or hand movements, for instance hardness (force required to slightly compress surface), stickiness (force required to separate fingers from surface), pushing force (degree of force needed to oppose a product’s compression), and plasticity (capacity to regain shape after having been deformed).
Figure 1. The functional model of haptic aesthetics

1. Low-level analyses (exploration)
   - Orthogonal exploration
     - Hardness
     - Stickiness
     - Pushing force
     - Plasticity
   - Tangential exploration
     - Roughness
     - Depth
     - Braiding
     - Slipperiness
     - Fibrosity
   - Measure exploration
     - Temperature
     - Weight
     - Size
   - Simple, unspecific processing

2. Mid-level analyses (assessment)
   - Absolute assessment
     - Symmetry
     - Closure
     - Contour
   - Relative assessment
     - Complexity
   - Integrative assessment
     - Coherence
   - Elaborate, specific processing

3. High-level analyses (evaluation)
   - Utilization evaluation
     - Usability
     - Ergonomics
     - Functionality
     - Intuitiveness
     - Attention
     - Adequateness
     - Practicality
   - Aesthetic evaluation
     - Innovativeness
     - Typicality
     - Idiosyncrasy
     - Arousal
     - Interest
     - Erhabenheit
     - Fascination
     - Seduction
     - Frustration
     - Liking
   - Integrative, associative processing

Context
Expectation
Integration
Familiarity
Cognitive & emotional aspects

Specified object
b) Tangential exploration

Tangential exploration refers to all haptic qualities that can be detected and explored by tangential finger or hand movements, for instance roughness (detection of relief, particles, harshness, etc.), depth (differences in haptically detected height), braking (force required to move forward on the surface), slipperiness (ease of ensuring continuity in sliding along the surface), and fibrousness (possibility of detecting fibers on the product’s surface).

Only a few studies examined aesthetic responses to specific haptic qualities: Ekman, Hosman and Lindstrom [36] reported preferences directly proportional to the softness of various sandpapers, cardboard and paper stimuli. Hilsenrat and Reiner [37] investigated preferences for the dimensions compliance (hardness) and roughness by using a forced choice paradigm showing that softer (88.5%) and smoother (92.3%) surfaces were preferred. These results are supported by a recent study of Klatzky and Peck [38, p.146] who measured the “touch-ability”. “Touch-ability” was defined as “[…] extent to which a pictured object invites contact.” Smooth surfaces and simple shapes of abstract objects also received higher touch-ability scores than rough, complex shapes. Thus, visual previewing provides information about haptically perceivable characteristics – please see also chapter IV, section 3 for more detailed information [39]. Expectations based on visual previewing will be discussed in the second feedback loop. To subsume: smooth and soft surfaces seem to be preferred when no specific contextual cue is given (e.g. abstract stimuli, sandpaper and paper stimuli). According to Klatzky and Peck [38], some local or structural features have more “touch-ability” or affordance character than others. Future research should therefore address such specific hedonics of surfaces. As noted, contextual cues can change or influence the way of processing at each level. Therefore, preferences can be modulated based on e.g. specific information or a specific situation. The discussed general preference towards smooth and soft surfaces can change due to the aim of the task or the intentions/goals of a person. Aesthetically evaluating the very same smooth surface as either being part of a book cover or being part of a hammer’s handgrip section will receive very different, if not contradictory, outcomes [40].

c) Measure exploration

Measure exploration refers to all haptic qualities that are typically explored by taking the object in the hand or enclosing it [32, 33]. This kind of exploration aims to determine properties that could also easily be measured by means of standard instruments like a thermosensor (perceived temperature or thermal conductivity), a scale (weight) or a linear measuring tool (size).

Feedback loop 2: Expectation feedback loop.

When low-level haptic analyses are executed, expectations can shape anticipatory procedures affecting sensory and motor processing. Such effects are particularly strong when the to-be-explored object can be visually inspected prior to haptic exploration [39]. For instance, if people visually perceive a car door handle that has a metallic look, they expect high thermal...
conductivity; any deviation from the expected values as a result of haptic exploration will lead to an increase of attention and, most likely, to further explorative effort with the aim of revealing the origin of this deviation. Expectations also provide important pre-settings for motor actions accomplished during the exploration procedure, for instance, the anticipation of a hard surface will increase muscle tension in order to make adequate contact with the material.

2) Level 2: Mid-level analyses (assessment)

The second level of elaboration is still quite simple for the most part but already includes steps further specifying the object. Compared to the first level, more global aspects are now assessed requiring temporal as well as spatial integration of local aspects. Consequently, we term the processes of the second level assessments to stress a more elaborate way of processing. They can be divided into three different types of operations:

a) Absolute assessment

An absolute assessment is, by definition, a process that assesses global haptic qualities on an absolute basis without comparing them to qualities of other objects. Examples are symmetry, closure and contour, which are all qualities that can be directly assessed through integrating local haptic aspects. These variables are well-researched factors in visual aesthetics and are candidates for also influencing haptic aesthetic responses. We know that haptic shape assessment is processed similarly to the visual domain [41]. Symmetry can likewise be assessed accurately under haptic conditions [42]. Visual findings indicate that symmetrical patterns [43-45] or symmetrical faces [e.g. 46, 47] are preferred compared to nonsymmetrical versions. Similarly to the studies reported at the first level, a visual preference bias towards curved objects (variable contour or angularity) was reported by several studies [48-50]. Recently, Jakesch and Carbon [51] replicated the effect under haptic conditions with 3D plotted stimuli but also revealed results that indicate high degrees of idiosyncratic processing. Similar to the first level, contextual cues might influence the processing of symmetry and contour. The preference bias for curved objects might be overwritten when specific goals concerning ergonomic aspects are more relevant. The preference can also be changed over a series of elaborate contacts with new forms via adaptation effects [52]. An extreme example is the creation of cuboid watermelons from Japan’s Zentsuji region for better transportation. In the next section, relative assessment is discussed. “Relative” refers to the fact that some properties cannot be assessed in an absolute fashion, but in relation to other items. This is true within a set of stimuli presented in the laboratory but is also influenced by the context: The subjectively perceived complexity of an object is supposed to change according to its surroundings.

b) Integrative assessment

Under the term integrative assessment we subsume processes that operate on a more global level and aim at the retrieval of information about the coherence of an object’s haptic qualities by integrating local aspects into a global Gestalt. As many different haptic dimensions have to be taken into account in parallel, this process seems to be quite elaborate and specific already. Paradigmatic members of this category are variables such as harmony, balance and rightness, which are of great importance with regard to aesthetic appreciation [56, 57]. In the visual domain, Rudolf Arnheim [58] suggested that “Good Gestalts” are generally more aesthetically appealing. Haptic grouping effects (grouping based on proximity and similarity) have already been tested to investigate if the haptic perceptual organization is similar to the visual perceptual organization [59]. Grouping based on similarity speeded up the performance in a haptic search task, whereas proximity did not influence the performance. Based on these results, future studies might examine the aesthetic appeal of such Gestalts in a systematic and elaborate way.

Feedback loop 3: Integration feedback loop.

Mid-level haptic analyses are shaped and re-tuned by an integration feedback loop where local aspects are integrated with regard to time and space to obtain assessments of more global aspects of the object. An even deeper level of integration will be reached when these more global aspects are themselves integrated to assess information on the coherence of such aspects.

3) Level 3: High-level analyses (evaluation)

The third level of elaboration refers to the last step of haptic aesthetic processing. It combines further integrative cognitive as well as emotional aspects: The haptic object that has been pre-processed during the preceding (perceptual) phases (exploration and assessment) is now associated and linked with other material, thus becoming integrated into the haptic habits [cf. 60]. The resulting final product of this process is the haptically specified object. For so-called evaluations, a term we will use here to indicate deep processing, cognitive as well as emotional aspects will be processed. On this level of processing two types of evaluative operations are available:

a) Utilization evaluation

Utilization evaluation refers to all haptic qualities that are linked with practical issues or the handling of the object, e.g. usability and ergonomic aspects as well as properties associated with functionality and intuitiveness of usage [see 61 for an
overview]. It also extends the analysis to attention-drawing properties, adequateness and practicability of the haptic design.

b) Aesthetic evaluation

Aesthetic evaluation encompasses those kinds of evaluative processing of the object’s haptic qualities that concern variables commonly linked with aesthetic value. The term aesthetic in this context is defined in accordance to Desmet and Hekkert [4] as capacity (of materials and objects) to please our haptic system. Besides explicit aesthetic measures like preference, appreciation, liking [62], interest [63], fascination, seduction, and frustration [4, 64], more implicit measures like cognitive and emotional arousal (as is, for instance, generated by uncertainty, ambiguity, understanding or surprise) [65], innovativeness [60], typicality and idiosyncrasy [66, 67] are candidates for aesthetic evaluation.

Feedback loop 4: Familiarity feedback loop.

In accordance with theories on visual perception stating that object identification and recognition will not occur until high-level aspects have been processed [68], we propose that identificatory processes take place at the point of high-level cognitive analyses of the haptic object but not before. As soon as an object is processed on such a sub-ordinate level [69], important information on its specific properties are available and the object becomes familiar. Familiarity and associated concepts of fluency and (proto)typicality are strong predictors for liking [67, 70, 71] and continuously contribute to further modification of the high-level process of evaluation. Specific research on affecting effects in the haptics domain is still rare, but recently it was found that phenomena like the mere-exposure effect can also be demonstrated for haptics: For complex stimuli, Jakesch and Carbon [72] found effects of exposure frequency leading to a significant increase in liking from fully unfamiliar via slightly familiar (touched twice before) to highly familiar (touched ten times before) objects that had only been haptically inspected. The reason for such familiarity effects might be that familiarity activates specific knowledge of the recognized object and associated requirements and demands, which consequently leads to tuning, shaping and biasing the initial evaluation. In the case of new products, familiar parts activate stored concepts e.g. of specific brands [73] and re-shape evaluative processes and consequently aesthetic as well as utilization responses. A coherent context might foster the detection of familiar elements or the general categorization of an object being familiar, whereas a dissonant context might slow down or even hinder the feedback loop process.

IV. IMPACT OF HAPTIC AESTHETICS ON DESIGN ISSUES

1) Necessity of a haptic aesthetics perspective

The present paper wants to stress the necessity of integrating a haptic aesthetics perspective into the analysis of the qualities and the utility of products. Undeniably, there are strong movements and efforts towards integrating considerations of haptic functionality into the development of new products. Important examples from an applied perspective are given, inter alia, by contributions in this special issue on perception-based media processing: For instance, force feedback interfaces for increasing the validity of data entries [74] or haptic rendering as an effective feedback modality for the emerging area of haptic media [74, 75]. Future product developments already show strong reliance on haptic controls using the “sense of touch” [76], although most efforts are in regard to utilization effects, still neglecting important effects of haptic aesthetics. As systematic knowledge as well as research on haptic aesthetics is still quite rare, future efforts should be strongly directed to this specific dimension of design qualities in general and haptic qualities in particular.

2) Creative ways to sensitize people to the relevance of haptic aesthetics

Helpful inspiration for how to sensitize people to the relevance of haptic aesthetics comes from the domain of art. Louvre’s “Tactile Gallery”, opened in 1995, explicitly allows haptically exploring, assessing, and evaluating artworks. The hereby evoked strategies for achieving knowledge of the pieces of art reflect the different levels of analysis figured out by the functional model of haptic aesthetics proposed in the present paper. Illustrating that aesthetic experience is far stronger, livelier and more sophisticated when the sense of touch is integrated into the perception of complex objects, the exhibition furthermore stresses the importance of systematically developing a specific theory of haptic aesthetics.

3) Cognitive and emotional aspects

A product can communicate through many different channels, and haptic aesthetics in this context seems to be particularly qualified for evoking cognitive as well as emotional reactions. With regard to typical human-product interactions the following aspects seem to be relevant: Haptic evaluation of products creates great opportunities to induce deeper cognitive processing of a product. If a product cannot be integrated into the “haptic habits” [compare “visual habits” in 60] as a consequence of an excessively high degree of novelty, it might be labeled as innovative or it might remain uncertain. If expectations concerning the product are not met by the haptic evaluation (e.g., when it is discovered that the surface material of a premium car’s dashboard has in fact a low haptic quality), (negative) surprise is produced. Haptic qualities that are not easily understandable and overstrain the perceivers’ processing abilities will probably lead to frustration (cf. Mikulincer [77] who found a clear relation between failure in problem-solving and frustration). Interest, in contrast, will result for haptic stimuli that induce low levels of understanding but are, at the same time, fascinating to the perceiver. Long-term fascination might yield seductive potential and lead to sustainable liking.

It is important to note that visual compensation for lacking or absent haptic information, i.e. a visual aesthetic compensation for low amounts of haptic aesthetics information, can hardly be an adequate strategy. This effect, which is particularly strong in people with a high “Need for Touch” [8], can be explained by Klatzky, Lederman and Matula’s [78] “visual preview model” that assumes a two-step processing of stimuli perceived on a visual and haptic basis: first, vision provides an optical snapshot of the haptic qualities; because of their inferential character this information is neither very reliable nor very fine-graded, but it meets the simple criteria required for generating a preliminary overview of the object’s haptic structure. In a second step, haptic qualities will be
analyzed by the haptic sense itself, which provides much deeper and elaborated information further enriched by so-called autotelic touch information [79]. Autotelic touch information includes, e.g., haptic pleasure, an important aspect of haptic aesthetics.

4) A case study for haptic aesthetics in consumer products
To demonstrate the impact of haptic aesthetics on a specific design issue we will shortly discuss a case study from the consumer product industries: typical control elements that automobiles are equipped with.

In the automobile sector, main aims with regard to constructing control elements are ensuring safety of usage, reducing cognitive demands for controlling processes, high perceived quality and pleasure of using. Aims related to safety and cognitive demands are requirements typically covered by ergonomic visual, but foremost haptic, design. Aims related to perceived quality and pleasure, to which we will shortly refer in the following, are directed mainly towards haptic aesthetics.

Perceived quality: The perceived quality of a product reflects the perceiver’s opinion about the product’s quality independent of the product’s actual physical qualities. High perceived quality will most often lead to high levels of liking, satisfaction or even fascination. In the given context, haptic aesthetics are of importance with regard to the design of knobs, buttons and switches [31, 80], as well as concerning the materiality of the main interior elements for interactive usage (steering wheel, gear switch, door handles) and the overall impression of base materials such as the roof liner or the seat cover. More specifically, to sketch an example related to the proposed functional model: the evaluation of various seat fabrics. Local aspects (like fibrosity, stickiness, plasticity, roughness / relief or perceived temperature) of the fabrics’ surface are used as the basis for high-level analyses. Based on previous experiences, actual needs and intentions (sporty interior vs. family-friendly interior etc.) the same texture parameters will be evaluated differently with respect to quality as discussed in the context feedback loop. Pleasure of using: Pleasure of using is hard to realize in an automobile as a consequence of strict safety guidelines that prevent overly playful gimmicks, but nevertheless specific haptic properties can lead to high aesthetic evaluations and can thus even create pleasure. There are several levels on which pleasure can be induced, important aspects are, among others, particularly comfortable or interactive seats, very intuitive and high-quality haptic control elements, or material of extraordinary haptic quality. Implementing according elements can create high levels of haptic aesthetics, bringing about fascination and pleasure. Haptic response in terms of haptic feedback, as realized by BMW’s haptic selector called iDrive, first introduced in the E65 7-series and further developed and integrated in other components by BMW’s CCC and CIC systems, gives adaptive feedback to the regarding user mode. iDrive’s controller knob integrates most of the configuration possibilities into one central system. As all systems to be coordinated during driving potentially draw attention away from the core job of a driver — i.e. the safe and precise handling of a car — haptic feedback is essential to distribute attention and cognitive processing on different modalities [see 81 see 81]. Haptic feedback also offers the pleasure of handling as the user gets a direct response from the system about the successful execution of a task.

5) Concluding remarks
Real fascination for a product often originates at a level that we call “haptic aesthetics” throughout the present paper. This is quite impressively documented by the ongoing market success of products of Apple Inc. that are emotionally charged due to an intense focus on haptic aesthetics. As mentioned above, visual compensation (or compensation by any other sensory modality) is often not very successful, as fascination, interest or aesthetic appreciation might just arise from one single, but spectacular haptic dimension or haptic feature.

Therefore, it is time to try and better understand the level of haptic aesthetics, and the pleasure that is frequently associated with it. Haptic research should, consequently, try to intensify investigative efforts as well as undertake the advancement of methods and the development of processing models for this thrilling and future-oriented domain.

ACKNOWLEDGMENT
C. C. C. thanks the organizers of the 2011 meeting of the Tactile Research Group (TRG) in Seattle, USA for inviting him to an inspiring symposium initiating this paper. The authors would like to thank Vera M. Hesslinger for deeply discussing and proofreading the text, Karon MacLean, Robert Kreuzbauer and three anonymous reviewers for their valuable comments and suggestions on an earlier draft of this paper.
REFERENCES
