SENSATION AND PERCEPTION IN SURFACE USING KANSEI SURFACE PROPERTIES, ENGINEERING

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ABSTRACT

Aesthetic properties of a product add significantly to meaning and relevance of a product. In this study, Affective Surface Engineering is used to illustrate and model the link between customer expectations and perception to controllable product surface properties. The results highlight the use of the Soft metrology concept for linking physical- and human factors contributing to the perception of products. In conclusions of the study, future research in Soft metrology is proposed to allow understanding and modelling of product perception and sensations.

Keywords: *Surface Texture, Affective Engineering, Industrial Design, Kansei, Surface, Perception*

1. INTRODUCTION

Organizations depend on their customers and therefore should understand current and future customer needs, should meet customer requirements and strive to exceed customer expectations. Consumer decisions when choosing a product comprise of a complexity of aspects including experience controlled by our five senses, fulfilling of functional requirements, and gestalt, describing the sum of the product properties. Here, tools and methods to measure customer satisfaction and link it to physical properties of products are of great interest.

The widely implemented ISO 9001 series are based on seven quality management principles whereof the first is ***Customer focus***. *"Sustained success is achieved when an organization attracts and retains the confidence of customers and other interested parties on whom it depends. Every aspect of customer interaction provides an opportunity to create more value for the customer.*

Understanding current and future needs of customers and other interested parties contributes to sustained success of an organization" [1].

Form, colour, gloss, material and texture selection are examples of critical product properties; and communicate a meaning to the customer. Well-polished metal surface and finely woven clothes may be examples of product properties specially designed to be appealing to the human sense of visual feedback and touch from products aiming at an exclusive high-quality market [2].

Material- and manufacturing selection is a complex process involving stakeholders from designer to, producer and user groups. Zoom into the material beyond what we can see with the naked eye, and the micro structure will expose a landscape in the sub mm scale affecting us as customers and users in a subtle way. When observing patterns, regularities in this semantic landscape and see relationship and correlations to certain experiences, these can obviously be represented by clustered words, here called Kansei words.

The aim of the paper is to present the importance and context of "Affective Engineering" and to support the discussion of continued research in the field –addressing the problem of the absence of a current joint approach to affective surface engineering in general.

2. EMOTIONS AND PRODUCT EXPERIENCE

2.1. From stimuli to sensation

The combined sensation of a products' surface gloss, colour, haptic properties like "friction", "elasticity", "hardness", and "temperature", create an intended message to the customer received as a stimuli (R) by the human five senses, transformed to psychological sensation (S). The Psychological Sensation (S) was expressed in "Fechner's law" as: $S=k \log R$ (1) where k is a constant and the Sensation following a logarithmic function where small differences in stimuli create a larger variation of sensation than for changes of stimuli at higher values [3].

Later S.S. Stevens at Harvard developed a similar model – "Stevens' power law", sensitive to that different types of stimuli follow different curve shapes to Psychological sensation: $S=aIb$,(2) where a is a constant, b is a stimuli exponent varying with the type of stimulation (visual, haptic, smell, taste, or audio) and I is the stimulus energy related to Stimuli (R) the "Fechener's law" in eq.1 above [4]. So to convey a "message" strong enough to the customer, thresholds for the lowest detection level of changes in stimuli and the function relating the stimuli to psychological sensation are important to understand.

Questions needed to be answered related to surface engineering are the minimum roughness of a handle the customer can sense and the differences of texture roughness allowing a handle with two textured parts to be perceived as having the same haptic roughness sensation, i.e defining thresholds for texture sensation and tolerance in relation to customer expectations and satisfaction.

2.2. Aesthetics and semantic scales to rate attitude

Aesthetics can be explained as the human perception of beauty, including sight, sound, smell, touch, taste, and movement, and the interpretation of the impression. But can also be explained as how a product present itself, its expression. Hidden factors controlling appreciation of beauty have been discussed by philosophers since the Ancients and was established as a subject of science when Osgood et al introduced the semantical differential method used to quantify people's perception of a product [5]. Here, a semantic scale composed of polar opposite adjective pairs separated by a five to seven point rating scale is used. For example, a customer could rate the perception and interpreted attitude to a product by grading adjective pairs (rough to smooth, cold to warm, dark to bright) on 7 grade scales. Semantic scales could then be evaluated using e.g. principal component analysis (PCA), to draw general conclusions of attitudes and separate them from more specific and subjective interpretations of surface properties.

2.3. Motivation and need

However, one important component affecting the Aesthetics and attitude to the products is the customers' need or motivation. Motivation and need of a customer was discussed by Maslow [6]. Here, 5 levels of motivation (Biological- and psychological needs, Safety needs, Belonging and love needs, Esteem needs and Self actualisation) were accentuated. If the psychological sensation (S) triggered by the physical stimuli matches the customers' expectation at the present motivation "level", the attitude to the product would be positive.

3. THE INTENDED PRODUCT MESSAGE

3.1. Designing the customer motivation

Schutte [7] added to the discussion of needs of the customer also the pleasures of motivation by Jordan's "4 pleasures" [8] -Physio – to do with the body and the senses. Psycho – to do with the mind and the emotions. Socio – to do with relationships and status and Ideo – to do with tastes and values. Jordan's 4 groups complete Maslow's five steps and their fulfilment at the different motivation levels is of importance when designing customer motivation into the product.

3.2. Design parameters and intention –the Affective Engineering Equalizer

Our motivation for- and how we perceive a product is strongly linked to the customers' "buy" decision. Industrial design methodology aims at creating this motivation and pleasurable product experience including meaning and message for the customer [9,10,11].

The aesthetic and pleasing properties of a product are of major importance in order to create motivation, interest, meaning and relevance of a specific product for the customer. Since there almost always exist alternative competitive products that fulfil basic required functionalities, the intended design of product properties towards increased customer motivation is one way of "making a difference" and standing out from the competition. The "Equalizer" introduced by Bergman et al. [12] in fig. 1 below, is a tool to visualize the relative importance of design element properties (form, material, colour and surface); how they are used and tuned for a given product to create the intended motivation, meaning and message, i.e. the aesthetics and core values, intended by the industrial designer.

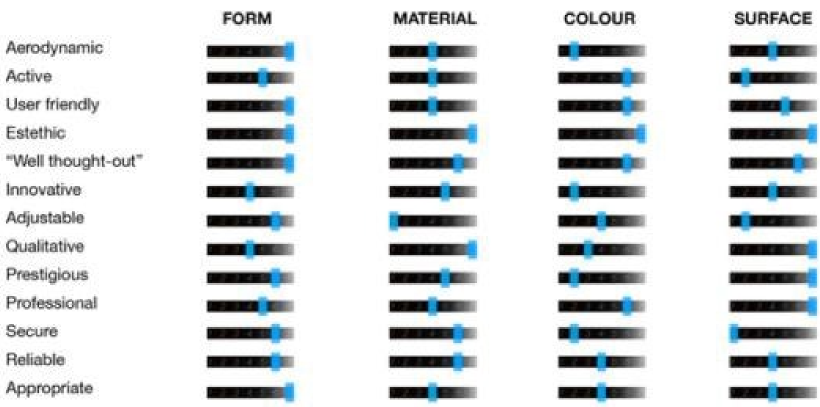

Fig. 1. The Equalizer with the design elements (horizontal scale) and the product intended core values or "product message" (vertical scale) and how the "tuning" of the "equalizer" setting creates the total perception and aesthetics of a product [12].

In the example from figure 1 above, the 13 core values are adjectives decided by the designers to define the product message of a roof-mounted bicycle carrier for the automotive industry

[13]. The design element surface is decided to have its highest importance on "user friendliness", "aesthetics", "well-thought out", "quality", "prestige", and "professional" and consequently surface properties like gloss, average roughness, texture, on the final product needed to be verified towards those core values for the successful product.

3.3. Ideaesthesia, and semantics, connecting design elements and product experience

Ideaesthesia can be defined as the phenomenon in which activations of concepts results in a perception-like experience [14] To objectively and transparently judge and measure how the specification of physical design elements create the expected subjective customer perception, i.e. creating ideaesthesia, is a complex task involving both physical metrology and perceptual evaluations. An example of ideaesthesia is the experiment made by the psychologist Wolfgang Köhler in 1929 [14], showing the strong correlation between the visual shape of an object and the speech sound (see below figure 2, top and middle) named the "Bouba-Kiki" effect. The word Lumumba is normally connected to the top and middle right "soft-large radii contour shape" image and the word Takete with the top and middle left "sharp angle, straight line contour shape" image. Today, a strong belief in the industrial designers' expertise and intuitive ability to make judgement exists and is regarded as "tacit" knowledge based on skills, ideas and experiences hard to formalise for an organisation.

A tool used frequently within the discipline of industrial design and strongly related to the ideaestathesia, to explain and formalise aesthetic knowledge is "Semantics" ,- the study of meaning and the relation between design elements and signifiers, like words, and symbols, and the correlation in between.

As an example of design semantics connecting design elements to core values –adjectives, is the "softening" of the perceived visual sensation in figure 2 from a sheet metal surface by mimicking a "soft" natural hair texture (bottom left) with the Angel Hair™ texturing1 (bottom mid), compared to the more traditional "hard" "Taketeteish" brushed steel texture (bottom right).

Fig. 2. Lumumba–Takete or Bouba-Kiki words (top and middle) and the meaning of form which has a strong connection to product experience. Takete to the left and Lumumba to the right. Beside is a typical soft hair texture (left) and the Angel Hair™ (middle) steel texture, mimicking hair and a brushed uni-directional steel texture (right).

3.4. Perceptual Product Experience, modelling the products' intended message

Perceptions involve any or all of the five senses. Understanding the structure of how this works can create a more robust and controlled process when designers create new concepts for a predicted user experience. The Framework of Perceptual Product Experience (PPE framework) [9,16] considers perceptual product experience as composed of three core modes; the sensorial mode including perceptions of stimuli experienced with any of the receiver senses, the cognitive mode, we understand, organise, and interpret and make sense of what we perceive, and finally the affective mode concerns itself with experiences that are affective: feelings, emotions, and mood states, as result of product perceptions (see fig. 3, mid, below).

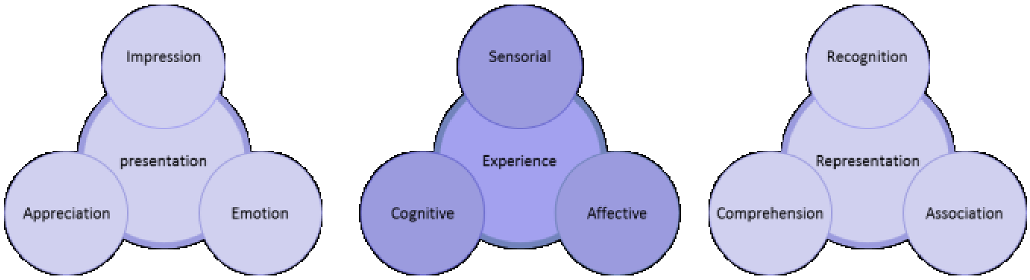

Fig. 3. The Framework of Perceptual Product Experience (PPE), after [9,16].

The PPE model in figure 3 below, illustrates a model for the intended product communication between the Producer and the Consumer. I.e. how the industrial designers' intended product message, semantics, expressed as core values, adjectives and converted into design elements with controlled properties creating consumer sensations, and ideally results in ideaesthesia, a pleasurable experience of the product at the customers motivation level.

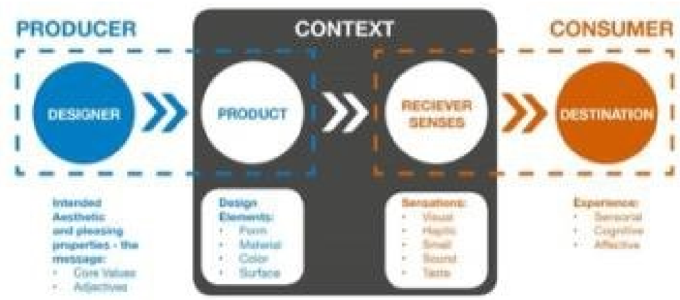

Fig.4. The figure illustrating a model for Intended product communication linked to the PPE Framework.

4. A "SOFT METROLOGY" FRAMEWORK TO MEASURE TOTAL APPEARANCE

4.1. Soft metrology –the measurement of customer satisfaction

Soft Metrology, is defined as "the set of techniques and models that allow the objective quantification of certain properties of perception, in the domain of all five senses" [17]. Soft metrology addresses a broad range of measurement, outside of the traditional field of physical metrology [17].

- psychometric measurement or perceived feeling (color, taste, odour, touch),
- qualitative measurements (perceived quality, satisfaction, comfort, usability),
- econometrics and market research (image, stock exchange notation), sociometry (audience and opinion),

- measurements related to the human sciences: biometrics, typology, behavior and intelligence.

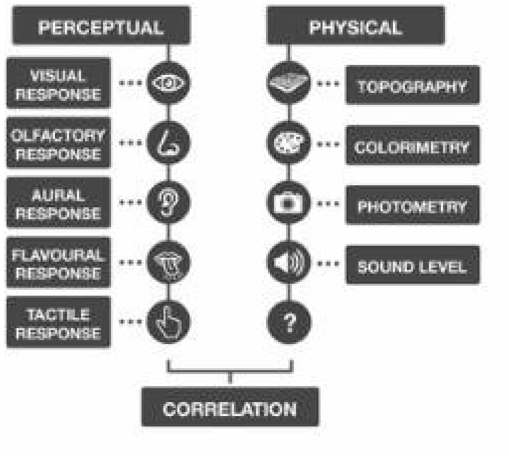

Fig.5. Soft metrology, correlating the objective physical measurements to human subjective perceptions, after [17].

Here the human would be considered as a measurement system defining sensitivity, repeatability and reproducibility and comparing the results with those obtained by methods from traditional “hard” physical metrology.

The notion of subjectivism can of course be discussed further related to figure 4 above. Parts of what is described as subjective, specific human responses in the figure above, can actually be described as universal and general perception, though subjective. Perceptions that can be generalized and therefore universal can be explained as “agreements” of how things are, like a clear distinction between milk, yoghurt and wine, not to be mixed up with preferences of the same in different contexts or time of the day.

The area of soft metrology has got a lot of attention and departments was formed both at the standards institutes NIST in USA and NPL in England [17,18,19] an European project - Measuring the Impossible (MINET) 2007-2010 with 22 partners from Europe and Israel including industries and academia as well as the national standards institutes in Great Britain, NPL and in Sweden SP [20]. In 2013 also L. Rossi published her doctoral thesis – “Principle of Soft Metrology and Measurement procedures in humans” stating the importance of the field [21].

4.2. Total appearance

Appearance is according to American Society for Testing and Materials (ASTM) [22] defined as “The aspect of visual perception by which objects are recognised”.

The visual appearance of an object is a result of the interaction between the object and the light falling upon it. Colour appearance is a result of the light reflection and adsorption by the pigments. Gloss is created by the reflection of light from the surface, and translucency is a result of the light scattering while the light passes through the object (fig. 6). The described complexity of the object's appearance causes different measurement technologies and instruments to be employed when attempting to quantify it [17]. Texture is a complementary component of the visual appearance and also needs to be considered.

The concept of total appearance, has been introduced to extend the concept of the appearance of an object. The total appearance, however, would require a description of the shape, size, texture, gloss and any other objects' properties possible to detect by our 5 senses (visual, haptic, smell, sound and taste) and interpreted by the brain as a "total appearance" of an object [17,23].

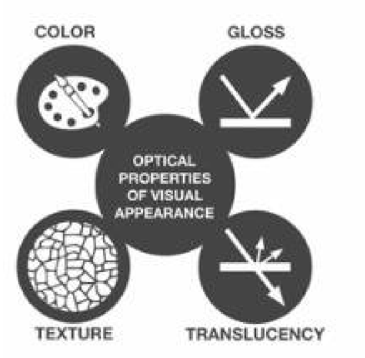

Fig.6. Visual appearance is one aspect of the total appearance. Here, the four basic optical properties (colour, gloss, texture and translucency) of visual appearance are grouped together.

The total appearance (fig. 7) could also be described as a combination of three aspects of appearance:

Physical aspect-physically detectable by our senses, Physiological aspect - creates a sensation via cortex (the neural effect when human receptors are subjected to the physical stimuli and convey signals to the cerebral cortex), creates a sensation via cortex

Psychological aspect created when sensations are interpreted by the cortex,

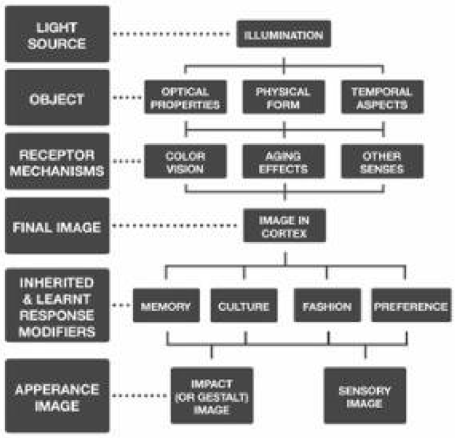

Fig.7. The concept of total appearance, after [17].

-the impact image, and the sensory image. The impact image is the initial recognition of the object or scene (the gestalt), plus an initial opinion or judgement. For the sensory appearance image, three viewpoints are used to create the total appearance, sensory, emotional and intellectual. The sensory viewpoint describe thoughts associated with the design elements of the object. The emotional viewpoint works the same, while the intellectual viewpoint covers other aspects associated to the object and situation rather than sensory or emotional associations [24,25].

Total appearance is closely related to the models of Intended product communication, and the Perceptual Product Experience (PPE) framework and could be used when quantifying customer perception and satisfaction using soft metrology to correlate physical and human factors contributing to products appearance images.

5. AFFECTIVE ENGINEERING, - TO MEASURE TOTAL APPEARANCE AND CONTROL THE CUSTOMER SATISFACTION

5.1. Quality Function Deployment and Kano to understand psychological sensation

After Osgood's publications [5] more methodologies e.g. Quality Function Deployment, QFD, and the Kano model were developed with similar motivation [26,27]. Those methods are very capable of dealing with psychological sensation but not as capable when it comes to translating the subjective sensation into design parameters i.e. real product features influencing the perceived sensation.

5.2. Kansei engineering –from subjective sensations to design parameters and total appearance

By using the framework of "Kansei-" Engineering (KE) [28,29,30,31]. as an approach and focusing on finding correlations between the functions; customer requirements, function requirements, design requirements and process requirements; a higher level of user quality and a methodology for soft metrology as discussed above could be obtained. According to Nagamachi the Kansei concept includes; "a feeling about a certain something that likely will improve one's quality of life". KE can also be defined as a customer-oriented approach to product development. The basic idea is that; the client's feelings shall be observed already at the phase of idea generation in the product development process, which then facilitate the project later on when a concept reaches the production stage.

Kansei engineering handles 6 different phases/steps [12,28,29,30,31]., starting with the definition of the products' domain and context, see figure 8 below:

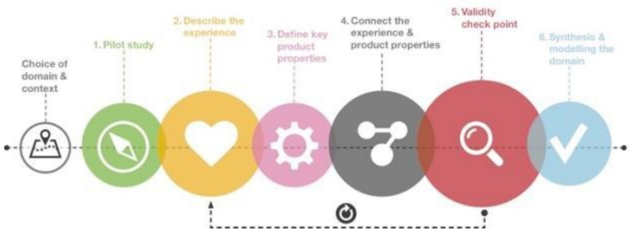

Fig.8. The Kansei based research approach and 6 different phases.

The 6 phases range from a pilot study where the product or service is defined including specification of the product and market, to synthesis and modelling the result of the given study. A full project ranging over all the 6 phases of Kansei engineering will result in a model or prediction of the total appearance or a limited sector of the total appearance, e.g. visual appearance or total appearance of the texture of a product within the domain selected in phase 1 of the project. Visual appearance is limited to optical factors of the product appearance while the total appearance of the texture of a product includes visual-, haptic- and other sensory aspects of the total appearance of the micro- or nanometre texture experience.

Below in following sections the Kansei methodology briefly described generally in picture 8, will be detailed and exemplified with results from current and past cases and studies to illustrate the potential of an application of affective engineering concepts on product surfaces.

5.3. Phase 1, The Pilot study, defining the domain

In this phase it is important to define product domain and users. Define and analyze: WHAT, WHO, WHERE, WHY, WHEN & HOW.

In the Pilot study The Design Compass" and persona studies as well as mood boards are used in order to make the definitions right.

5.4. Phase 2, Describe the experience

Define the Product experience (Span the semantic space) – In this phase it is important to find psychological emotions and expected total appearance and perception related to a product expressed as adjectives -"Kansei words", and grouped in logical clusters (see fig.10).

The idea of describing the product experience using adjectives is about framing the emotional functions, i.e. defining the expected perception and total appearance. To be able to do that there is a need to "span the semantic space", collect the expressed "emotions", by collecting adequate describing words, which the user expresses when interacting within the product domain.

5.5. Phase 3, Define key product properties

Define Key Product Properties (Span the space of properties) – In this phase it is important to find physical product properties that affect the user. Analyse the properties of the domain • Define properties that affect • Isolate significant properties.

When the identification of the core-values and Kansei words is made, the next step is to identify properties, design elements, of the existing product that can be controlled and affect the product towards those core values. The design elements should be appropriately measurable using standardized methods and parameters like the surface texture field-, stratified- and feature parameters in accordance with acknowledged ISO 25178 series of standards.

5.6. Phase 4, Connect the experience and product properties

Connect the experience,-the Kansei adjectives, and Product physical properties– By using qualitative studies on focus groups connections between Kansei words and design elements can be made. An important tool to visualize the connection between Kansei words and design elements contributing to the total appearance is the "equalizer".

For a given domain identified in step 1, the key product properties –design elements from phase 3 are connected to the Kansei words from phase 2, in this 4'th step by, for example, using focus groups.

5.7. Phase 5, Validity checkpoint

Validity Checkpoint – When the correlation in the Synthesis in step 4 is established, it is important to verify the results by statistical tests, experiments or virtual simulation.

The validity checkpoint is about an overall validation of the concepts total appearance, verifying quantitatively the Kansei words from phase 2 and their connection to the design elements obtained in phase 4.

5.8. Phase 1, Synthesis and modelling the domain , – Design and validation of a "prediction model".

The final step is intended to create a model that combines, refines and describes the results from the previous five phases in the Kansei methodology. Hence, to assemble a model bridging the emotional semantic- and product properties' space.

In this step, a design manual can be made in order to link design elements with Kansei words. [36, 37]. The design manual basically linked surface geometrical properties (the significant design elements and properties) to the Kansei words according to the results demonstrated in step 5 above. . In practice this resulted in designer rules collected in a physical booklet for the context of sauna wall panels.

6. CONCLUSIONS AND FUTURE

The aesthetic and pleasing property of products is one of the major design dimensions in order to create a meaning and relevance of a product. The correlation of objective characterization of material properties in relation to human response is the main component in Soft Metrology, a concept previously introduced and known, naming the methodology with the power of enabling affective surface engineering.

- Total experience can be used when quantifying customer satisfaction using Soft metrology correlating physical- and human factors contributing to products appearance images.
- Soft Metrology allows the objective quantification of certain properties of perception, in the domain of all five senses, i.e, a quantification method for measuring total appearance.
- Affective surface engineering using the Kansei method is effective to connect the expected sensation, using Soft metrology methods, to validated design parameters.
- The Affective-, Kansei surface engineering methodology has a great potential to help organisations to maintain customer focus by allowing industrial designers to understand and model a desired perception and total appearance of a product.

The results from the paper discuss a current direction in product development and industrial design where surface engineering and the concepts of soft metrology, total appearance and affective, Kansei, engineering are combined. Future possibilities to increase the generality and applicability lies firstly in the development of soft metrology to enable detailed understanding and modelling of the customer perception and total appearance.

Secondly, the development of software tools supporting and optimizing the 6 phases of Affective, Kansei, surface engineering will increase the accessibility and interest for the method and increase the number of performed case studies, thus increasing the knowledge in this emerging research area.

Thirdly, there exist a possibility and a need of further research into the development of the word “metrology” in soft metrology, where multisensorial physical data will be linked to human multisensorial perceptual data. Finally, the question of “How and to what level can we quality assure soft metrology data in turn assuring the quality of affective-, Kansei engineering approaches?” need to be addressed in future studies.

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